THE

FOUNDRY TRADE JOURNAL

WITH WHICH IS INCORPORATED

THE IRON AND STEEL TRADES JOURNAL

VOL. 63 Thursday, July 4, 1940 No. 1246

PUBLISHED WEEKLY

Subscription Terms: 17s. 6d. per annum.
Foreign and Colonial: 20s. per annum.
All Subscriptions are payable in advance.

THE FOUNDRY TRADE JOURNAL
49, Wellington Street, London, W.C.2.

EMERGENCY ADDRESS
to which all communications should be sent until further notice:—
3, Amersham Road, HIGH WYCOMBE, Bucks.
Telegraphic Address: "Zacatecas, High Wycombe."
Telephone: HIGH WYCOMBE 1792 (3 lines).

OFFICIAL ORGAN OF

The Institute of British Foundrymen

The Institute of Vitreous Enamellers

The Welsh Engineers' and Founders' Association

The Foundry Trades' Equipment and Supplies Association

Institute of British Foundrymen

PRESIDENT: 1940-41

W. B. Lake, J.P., Lake & Elliot, Limited, Braintree, Essex.

LIST OF SECRETARIES—

General Secretary: T. Makemson, Saint John Street Chambers, Deansgate, Manchester, 3. London Office: 49, Wellington Street, London, W.C.2.

Birmingham, Coventry and West Midlands: A. A. Timmins, A.I.C., 21-23, St. Paul's Square, Birmingham, 3.

East Midlands: S. A. Horton, "Three," Mostyn Avenue, Littleover, Derby.

Lancashire (*pro tem*): A. Boyes, "Roseville" 7, Kirkstall Road, Davyhulme, Manchester.

London (*pro tem*): H. W. Lockwood, Stewarts and Lloyds, Limited, Winchester House, Old Broad Street, E.C.2

Middlesbrough: (*pro tem*): J. K. Smithson, North-Eastern Iron Refining Company, Limited, Stillington, Stockton-on-Tees.

Newcastle-upon-Tyne: C. Lashly, Sir W. G. Armstrong, Whitworth & Company (Ironfounders), Limited, Close Works, Gateshead.

Scottish: J. Bell, 60, St. Enoch Square, Glasgow.

Sheffield: T. R. Walker, M.A., F.I.C., 11, Broomgrove Crescent, Sheffield, 10.

Wales and Monmouth: J. J. McClelland, 12, Clifton Place, Newport.

West Riding of Yorkshire: S. W. Wise, 110, Pullan Avenue, Eccleshill, Bradford.

South Africa: F. C. Williams, Mutual Building, Corner of Harrison and Commissioner Streets, Johannesburg.

Bristol: A. Hares, Park Crescent, 648, Stapleton Road, Bristol, 5.

Burnley: H. Buckley, Ellsmere, Norfolk Avenue, Burnley, Lancs.

East Anglian: J. L. Francis, 12, Glenhurst Avenue, Colchester Road, Ipswich.

Falkirk: T. R. Goodwin, "Viewfield," Falkirk Road, Bonnybridge, Scotland.

Lincoln: E. R. Walter, M.Sc., The Technical College, Lincoln.

The Institute of Vitreous Enamellers

President: Professor J. H. Andrew, D.Sc., Department of Applied Science, The University, St. George's Square, Sheffield.

Chairman: W. H. Whittle, W. H. Whittle, Limited, Eccles, near Manchester.

Hon. Secretary: Dr. G. T. O. Martin, 49, Wellington Street, Strand, London, W.C.2.

Foundry Trades' Equipment and Supplies Association

President: G. E. France, August's, Limited, Thorn Tree Works, Halifax.

Secretary: K. W. Bridges, Grand Buildings, Trafalgar Square, London, W.C.2.

Welsh Engineers' and Founders' Association

President: W. E. Clement, Morfa Foundry, New Dock, Llanelly.

Secretary: J. D. D. Davis, 9, Royal Metal Exchange, Swansea

BRITISH CAST IRON RESEARCH ASSOCIATION

The Registered Office and Laboratories of the B.C.I.R.A. are:—
21-23, ST. PAUL'S SQUARE, BIRMINGHAM
Telephone: Colmore 4274-4275 Telegrams: CIRA
The B.C.I.R.A. Scottish Laboratories are:—
Foundry Technical Institute, Meek's Road, Falkirk
Telephone: 332

Contents

	PAGE
Industrial Production	1
Photo-Electric Measurements of Spark Spectra	2
Crackings of Die-Castings made from Hardened Tin	2
Random Shots	2
Effect of Varying the Silicon Content of Cast Iron	3
Double-Acting Water-Cooled Compressors	4
Stainless Steels	4
Effect of Hydrogen on Various Steels	4
Gravity and Pressure Die-Casting	5
An A.R.P. Course for the Public	6
New I.B.F. Council Members	6
Publication Received	6
Production of Pressure-Resisting and High-Duty Iron Castings	7
Temperaments of Melting Units	10
Founders' Forum	11
Catalogue Received	11
Corrosion-Resistant Bearing Alloys for Chemical Plant	11
Vitreous Enamelling Section—Glass Technology as Applied to the Study of Vitreous Enamels	12
Strength of Vitreous-Enamelled Sheet	13
The Week's News in Brief	14
Forthcoming Event	14
Raw Material Markets	16

Industrial Production

For some time the Government have been endeavouring to devise a scheme which would be an improvement on existing arrangements for keeping under review the industrial production of the country during the war. In recent years a good deal of research work in this connection has been carried out but it has become necessary to complete and amplify this information in order to give it practical use during this critical period when the resources of the nation are being marshalled for a supreme war effort. The object of the scheme therefore is to obtain a complete picture of the labour and materials needed by all sections of industry, and to relate them to the sources of supply. This will enable supplies of particular materials from abroad to be adjusted, so that manufacturers may be provided with their essential needs at the time they are required.

After careful study the Ministry of Supply have decided to produce and publish a Product Code Book containing the bulk of the products normally manufactured in this country and also imported from abroad. These will be entered as types and not as proprietary articles nor as particular patterns of products made by individual firms, excepting in the case of certain purely military stores. Thus a locomotive or a mouse trap would be designated as such. The Code number of each product will be in three parts: (1) A three-digit number distinguishing the trade or industry which normally manufactures the products; (2) a three-digit number distinguishing the group to which the product belongs; and (3) a two-digit number distinguishing the product itself. For instance, the code number of "Gimlets" is 046/032/12. The first number represents the trade (toolmaking and cutlery trade), the second number represents the group (carpenters' and joiners' tools), and the third number the product itself (gimlets).

The new Code Book is expected to contain altogether about 6,000 products, both civil and military. In connection with each product a breakdown sheet will give particulars of raw materials and man-hours required for its manufacture. Taking the instance of a locomotive there would be required so many tons of foundry pig-iron, scrap iron, steel forgings, steel plates, and so on. Materials in smaller quantities like brass and gunmetal, white metal for bearings, etc., would be expressed in hundredweights. Things like pressure or vacuum gauges and other small items of equipment which the locomotive builder purchases, are not, of course, entered in the list of materials used, as they will be recorded in a breakdown sheet filled in by the manufacturer of "gauges." All the locomotive builder includes in his requirements is the number of gauges for the engine he is building.

An interesting feature of this particular breakdown sheet and indeed of any sheet for a manufacture requiring several months to build, is that a column is provided in which against every item is indicated whether it is required in the first, second or third month. Paint, for instance, would not be required until the locomotive was finished, so that there would be no need to hurry that forward if paint was required immediately elsewhere. Further, in the materials required, has to be included the quantity of wood needed to make the packing case, if any, weight of nails, and also, for shipping purposes, the number of cubic feet the packing case will occupy. One other point should be mentioned. The total materials required for a given manufacture is the gross figure which allows for the usual waste and scrap. The net figure, however, also is entered in the breakdown sheet.

Where a manufacture is small, such as, for instance, a gimlet, obviously the materials used would be trifling; moreover, such things are usually made by the hundred or by the gross, and it would be on one or other of these denominations or even a larger number that the quantities of materials required would be based.

The great advantage of the scheme is, where a firm has a foreign order for a certain large manufacture or for a number of smaller ones, the Ministry of Supply merely have to turn up the breakdown sheet for the particular product, and can then see at a glance roughly the materials required, when they will be needed, when the order will be completed, and how much shipping space must be provided. The manufacturing industries and the country generally should benefit very considerably from the information now being collected, especially if in addition to our war pre-occupations, a surplus of goods can be provided for shipment overseas.

Photo-Electric Measurements of Spark Spectra

As is well known, the outstanding advantage of spectrum analysis applied to furnish quantitative results, as compared with other analytical methods, is that an accurate value is obtained quickly without resorting to a preliminary chemical separation of the components or elements of the mixture under analysis. Many improvements in the details of the procedure of quantitative spectrum analysis have been made during recent decades, the majority of which have given a higher degree of accuracy in the results, so much so that more recently principal attention has been turned to curtailing the time required for making an analysis. American investigators have published various Papers on this subject, notably Vincent and his collaborators, who were primarily concerned with the method as applied to metals. In Germany, other developments have been in the direction of measuring the intensity of the spectral lines by direct photo-electric means using photo-cells and suitable galvanometers or electrometers. The main advantage of photo-electric measurements over the photographic-plate method is that many sources of error to which the latter method is subject are entirely eliminated. The photo-electric method has indeed been exhaustively tested, using a flame for energisation in order to obtain the greatest uniformity in excitation, the results showing that it is applicable for the estimation of a large number of elements. Having thus proved satisfactory for flame spectra, its applicability to the measurement of line intensities in the case of spark spectra was next studied.

To facilitate the direct photo-electric estimation of elements in spark spectra, G. THANHEISER and J. HEYES indicate in their report in the "Mitteilungen aus dem Kaiser-Wilhelm-Institut für Eisenforschung zu Düsseldorf" that the light emitted by the sparks can be resolved into partial beams and each partial beam then studied separately with the spectroscope. From each partial spectrum one line is then separated by a diaphragm and the intensity of this line measured with a photo-electric cell. The photo-currents obtained are measured by two observers using two electrometers functioning on the charge-measuring principle and the ratio of the charges over a certain period determined. Under standard conditions of measurement, these values are proportional to the ratios of the line intensities, and with the aid of the usually linear relationship between line intensity and concentration of the element in the specimen under analysis these values enable the content of the element in question to be calculated.

An examination of the accuracy of measurement offered by this method showed that a proportionality exists between the luminous intensity and the electrometer charge. If the two monochromatic systems used are adjusted to the same line, the mean error in the ratio of the electrometer charges was found to be 1.3 per cent. for the constant luminous intensity of the mercury arc and 1.5 per cent. when using the spark across silver electrodes. While the application of the method to the direct determination of copper in aluminium showed that the intensity of the copper line 3247.5 did not increase linearly with the concentration of the copper in the sample, the same divergence being also found in the estimation of copper from flame spectra, the determination of magnesium and manganese in aluminium revealed that there was a linear relationship between the line intensity and the concentration. The results obtained on such direct measurement were then compared with those obtained spectrographic-

(*Continued at foot of next column.*)

Cracking of Die-Castings made from Hardened Tin

An American correspondent of the International Tin Research and Development Council is manufacturing ice-cream moulds which are gravity die-cast from practically pure tin to which, for the sake of hardness, is added 0.5 per cent. each of antimony and copper. Cracks were sometimes found in the castings, and were thought by the firm's customers to have occurred during transit from the works. The Council was asked to suggest a remedy.

Generally speaking, cracks in such a material occur not infrequently during the final stage of solidification of the casting, due to shrinkage stresses. In casting practically pure tin it has always been found that the trouble is due to traces of lead. Apparently, at the final stage of solidification of the metal, a film of liquid constituent remains at the grain boundaries for an appreciable time after the rest of the casting has solidified, and the boundaries are thus liable to be pulled apart by the shrinkage stresses.

The remedy is, therefore, either to use a grade of tin extremely low in lead, or to increase the amount of alloying constituents sufficiently to make the material pasty toward the end of the solidification process, so that, being slightly plastic, it may yield to the stresses without cracking. Tin-base die-casting alloys containing 10 per cent. or more of additions are not subject to this form of cracking for the latter reason.

An alloy containing 0.5 per cent. each of antimony and copper, the balance being tin of high purity, was compounded, and castings made from it were free from cracks. About 0.05 per cent. lead was then added, and all the castings cracked. The antimony and copper contents were then raised to 1 per cent. each, so as to give some plasticity during final solidification, and the cracking was no longer obtained, even with the same lead content. Since in the case cited a comparatively small proportion of the castings cracked, it would be expected that a considerably smaller amount of lead was actually present, and that the increase of the antimony and copper contents to 1 per cent. would be an ample safeguard.

TO MEMBERS OF THE INSTITUTE OF BRITISH FOUNDRYMEN

It is the earnest desire of the President and Council that members should discuss in writing the various Papers which were prepared for presentation at the abandoned Cheltenham Conference. It is a courtesy and an act of appreciation they owe to the authors. Your comments should be sent to Mr. John Bolton, St. John Street Chambers, Deansgate, Manchester, 3.

(*Continued from previous column.*)

ally with the same specimens, the magnitude of the divergence of the individual values being calculated with reference to a straight-line correction curve:

In toto, the experiments made have shown that the quantitative estimation of elements by means of spark spectra using direct photo-electric measurements of the line intensities provides acceptably accurate data, but the utility of the method depends on the provision of suitable optical apparatus, whose efficiency must be such as to allow full advantage to be taken of the inherent value of direct measurements, particularly as regards the speed of determination.

Random Shots

"There is only one safe place in this dreadful world, and that's Heaven," remarked a youngster the other night when being escorted to an underground shelter during an air raid. One dear old gentleman, whose rooms are situated on the seventh floor of a block of flats now the temporary offices of his firm, must have felt that at least it would have been a simpler task for him to fly up to "that safe place" rather than to trudge down to the shelter without the aid of the passenger lift. He did it, however, and was just settling down in the camp chair reserved for him when he discovered that he had forgotten his gasmask. With the independence of the Scot that he was, he refused an offer from a junior member of the staff to "nip up" and fetch it, and he slowly and carefully made his way back to his quarters (seven flights up and seven flights down, mark you). "Well, well," he thought as he subsided again into his chair, "that's over without any mishaps." But, turning to say as much to a colleague, he discovered that he'd left his teeth behind! This time, he slunk off quietly without any fuss, feeling a little silly without his teeth and apparently without any presence of mind. Up he went again to fetch them. "Seven flights up and seven flights down," he reminded himself with bitterness, "but, after all, how can a man meet the situation with a stiff upper lip if he has no teeth behind to support it?" Nevertheless, once he had settled himself down again to await the "all clear," visions of all that was dear to him arose before his mind, as so often happens in times of danger. The dearest possessions in all the world lay away up in that top room (seven flights up and seven flights down) mute and helpless in a corner. The very thought of it and the vast space which separated them filled him with confusion. "My darlings," he cried, "I've left them upstairs," and with that he dashed out of the shelter, all calmness deserting him. His colleagues, shrugging their shoulders, merely murmured "Cats, possibly." Imagine the uproar of mirth, then, which filled the room when about five minutes later, a weary figure appeared at the door with a violin tucked under each arm, a benign smile of content on his dear old face at last.

* * *

"Are you still working for the same people?" asked a man of a pal he had not seen for some time.

"Oh yes," was the reply, "still the same people; missis and three kids!"

* * *

Rumour hath it that Germany has struck a new medal for fifth column traitors. It takes the form of a double cross.

* * *

The correct way to pronounce the name "de Gaulle," according to "Peterborough" of the "Daily Telegraph," is "goal," but an Anglo-French friend says that he is perpetrating the usual English fault in the pronunciation of French by sounding one "l" instead of two. Undoubtedly he is right, but the Englishman will still go on saying "goal," for that is a word he can understand. (Who would not wish for as many shillings as times that word is used in England in one winter alone?) Anyhow, is it not just to rid France of that second "l" that the French National Committee has been formed in London?

"MARKSMAN."

A Severe Test for Enamel

A vitreous-enamelled refrigerator taken from the salvaged American submarine "Squatus" was found to be in perfect condition in spite of being at the bottom of the ocean for over four months. On examination it was found to be coated with a mixture of diesel engine oil, battery acid and crystallised salt. It was made by the Herrick Cold Storage and Refrigerator Company, and enamelled by the Toledo Porcelain Enamel Products Company.

Effect of Varying the Silicon Content of Cast Iron*

By FREDERICK G. SEFING

The use of silicon to control the mechanical properties of grey iron has been known for many years. Early investigational work developed the fact that increasing the silicon lowered the strength and hardness and decreased the density. This was true for the irons containing 3.40 to 3.75 per cent. total carbon used in these early investigations. These effects of silicon were so well established that metallurgists have presumed silicon to have the same effects on grey iron of lower total carbons.

It has been found in the investigation reported in this Paper that increasing the silicon content in progressively lower total carbon irons tends to increase the tensile strength. Furthermore, sectional sensitivity decreases with increasing silicon from 1.00 per cent. to the level which produces a fully pearlitic structure, beyond which the section sensitivity again increases at lower hardness levels. The results presented here show that the tensile strength increases about 2 tons per sq. in. for each 0.25 per cent. drop in total carbon from 3.50 to 2.75 per cent.

Production of Test-Bars

Four series of irons, including 13 heats of 250 lbs. each, were made in an indirect-arc electric furnace. The same base metals, pig-iron, cupola remelt pigs, steel and ferro-silicon, were used in varying proportions to produce the four series of irons whose total carbons were 2.75, 3.00, 3.35 and 3.50 per cent. The silicon content of each series was varied between 1.25 and 2.50 per cent. The analyses of each tap are given in Table I.

The procedure was the same for each heat in order to reduce the variables of melting practice to a minimum. All the materials for the heat were charged into the hot furnace, varying the proportions of steel and the pig to obtain the desired carbon content and making suitable ferro-silicon additions to the cold charge to obtain the desired silicon. The melt was ready to be tapped at 1,530 to 1,565 deg. C. in from 50 to 75 min.

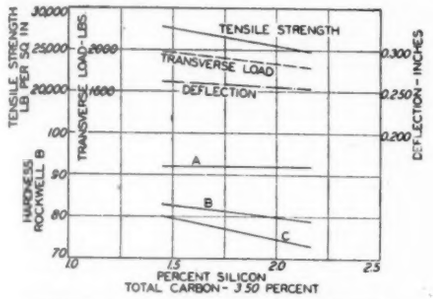


FIG. 1.

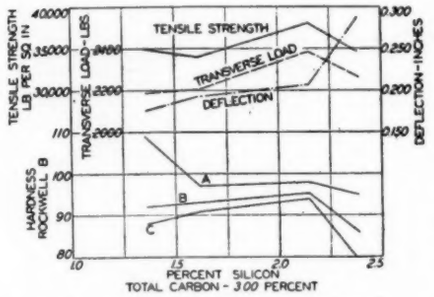


FIG. 2.

FIGS. 1 AND 2.—TENSILE-STRENGTH, TRANSVERSE-STRENGTH, DEFLECTION AND HARDNESS VALUES OBTAINED WITH VARYING SILICON PERCENTAGES ON CAST IRONS CONTAINING 3.50, 3.35, 3.00 AND 2.75 PER CENT. TOTAL CARBON.

Note.—Transverse-strength, deflection and tensile-strength values obtained on 1.2-in. dia. arbitration test-bars. Hardness values are given for each of the test-bars cast. A = ½-in. by 1-in. by 6-in. bar. B = 1.2-in. by 21 in. arbitration bar. C = 2-in. by 4-in. by 6-in. bar.

TABLE I.—*Chemical and Physical Properties of Electric Furnace Heats.*
(Mn 0.6, S 0.03–0.04 and P 0.16–0.18 per cent.)

Heat No.*	T.C. per cent.	Si.* Per cent.	Transverse.		Tensile strength, lbs. per sq. in.	Brinell hardness.	
			Load, lbs.	Def., in.		Large bar.	Arb. bar.
74	2.78	1.47	2220	0.162	16.4	210	217
70	2.72	2.01	2575	0.187	18.5	201	220
71	2.71	2.25	2435	0.170	18.7	217	226
72	2.72	2.48	2335	0.169	17.9	215	220
75	3.00	1.37	2190	0.176	15.6	181	204
76	3.06	1.61	2205	0.193	15.3	183	206
77	2.89	2.15	2385	0.207	17.0	195	215
82	3.02	2.40	2265	0.288	15.5	148	183
84	3.33	1.26	2090	0.217	13.8	158	183
83	3.32	1.55	2070	0.224	13.9	160	183
85	3.36	1.94	1980	0.221	13.5	156	183
80	3.52	1.44	1990	0.262	12.4	153	163
81	3.50	2.16	1835	0.254	11.1	138	161

*Includes 0.10 per cent. Si. as a ladle addition.

While tapping weighed 100-lb. portions of the melt, 0.10 per cent. silicon, as 85 per cent. ferro-silicon, was added to the ladle. The metal was poured into the moulds at 1,426 to 1,454 deg. C. Each 100 lbs. of metal was poured into the following moulds:—One mould of two bars, 2 by 4 by 6 in.; one mould of two bars, ½ by 1 by 6 in.; and six moulds of one arbitration bar, 1.20 in. dia. by 21 in. long (A.S.T.M.—A48-36). The rectangular bars were made in horizontal green-sand moulds, held to constant specifications and rammed to the same hardness. The arbitration bars were made in dry-sand vertical moulds. The castings were cooled to room temperatures in the sand.

Tests

Rockwell hardness tests were made on each type of test-bar and Brinell hardness tests were made only on the two larger sizes. Accurate Brinell hardness readings could not be obtained on the small bar. The hardness tests were made on each size on a surface cut through the centre of the 6-in. length of the rectangular bars and near the centre of the arbitration bars. One reading was taken in the centre and two midway between the centre and edge. The average of these six readings (two bars) was regarded as the hardness of the casting and is given in Table I.

Two arbitration test-bars from each tap were tested for transverse load, deflection and tensile strength, according to the methods set forth in the A.S.T.M. specification A48-36. These values also are tabulated in Table I. Each transverse load, deflection and tensile strength value given in Table I is an average of two readings. Each hardness value of Table I is an average of six readings. For each heat, two complete sets of values are given, one for each tap, to show the constancy in properties of each heat. The averages of the values for each heat were used to prepare the set of curves shown in Figs. 1 and 2.

Discussion of Test Data

From Figs. 1 and 2, it will be seen that the spread of hardness between the light and heavy castings increases with increasing silicon in the 3.50 per cent. total carbon iron. Furthermore, the tensile strength of this series of irons decreases as the silicon increases. When, however, the effects of silicon on the 3.35 per cent. total carbon iron are observed, the spread of hardness between the light and heavy castings decreases up to 1.50 per cent. silicon and remains constant up to 2.00 per cent. silicon. There is no appreciable change in the strength properties of this carbon level with the silicon varying between 1.25 and 2.00 per cent.

In the series of irons containing 3.00 per cent. total carbon, there is a marked decrease in the section sensitivity as the silicon increases to 1.60 per cent. It remains constant then as the silicon increases from 1.60 to 2.15 per cent. beyond which the section sensitivity again becomes evident at lower hardness levels. It also will be noted that the tensile strength remains about the same as the silicon increases. The slight increase in strength in the 2.15 per cent. silicon iron is probably due to the 2.90 per cent. total carbon.

(*Continued on page 6.*)

* Slightly condensed from a Paper read before the Chicago Convention of the American Foundrymen's Association. The author was formerly Assistant Professor of Mechanical Engineering, Michigan State College, East Lansing, Mich., and is now Metallurgist, International Nickel Co., Inc., New York.

Double-Acting Water-Cooled Compressors

The compressors illustrated have been designed by Worthington-Simpson, Limited, to meet the demand for high-speed water-cooled machines of relatively small outputs suitable for direct coupling to electric motors or belt drive, as the case might be. The compressors are built in a range of sizes with piston displacements from 100 to 900 cub. ft. per min. and pressures from 50 to 150 lbs. per sq. in. for the single- and two-stage machines respectively. On general lines the construction of the machines follows accepted principles, embodying at the same time the latest improvements and refinements.

In the two-stage machine, the first stage of compression takes place in the space above the larger diameter of the piston and the second stage in the annular space around the bottom end of the piston. The air from the first stage is cooled through an intercooler of special design. The cooling elements are independently attached to a rectangular cover which forms a complete unit and bolts directly on to the cylinder block. The elements are arranged to give complete drainage through cocks in the casing, and are accessible for examination and replacement if necessary.

The cooling water enters the cooler casing with a directional flow over the cooling elements and afterwards to the water space around the cylinder, cylinder head and valves. The cylinder and cover, also suction and delivery passages, are completely water-jacketed, insulating the hot discharged air from the incoming atmospheric air. This is a very important feature, as the valves operate under the coolest possible conditions, thereby maintaining a high efficiency and eliminating carbonisation.

In the single-stage machines compression takes place on both sides of the piston from a common suction to a combined discharge. Apart from the elimination of the intercooler, which is replaced with a cover, in which is incorporated the combined suction branches, the single and the two-stage units are identical. The valves are of the multi-port, large-diameter, low-lift type, all suction valves being fitted with unloading gear.

The standard Worthington-Simpson method of regulation is employed. This operates by holding the inlet valves open during the unloaded period, when the air passes in and out of the cylinder without compression. Where the demand for air is intermittent for long periods, the automatic electric start and stop control is recommended, otherwise the constant-speed control is preferable. The first- and second-stage air-pressure and oil-pressure gauges are mounted on the machine.

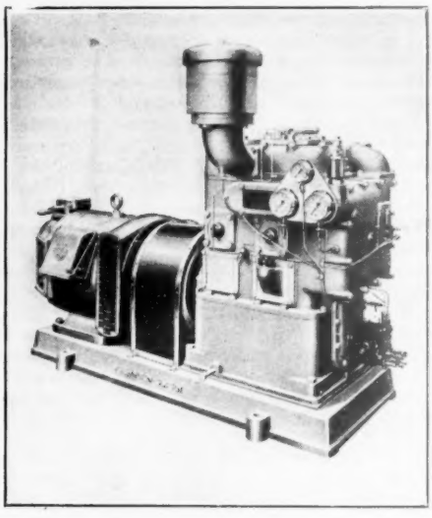


FIG. 1.—DIRECT-COUPLED MOTOR-DRIVEN DUPLEX TWO-STAGE COMPRESSOR.

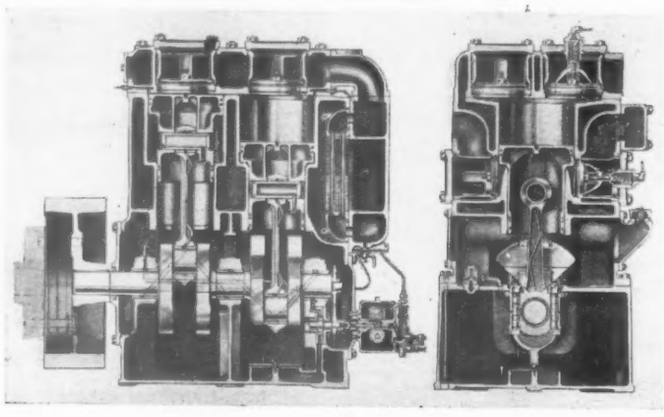


FIG. 2.—SECTIONAL ELEVATIONS OF DOUBLE-ACTING WATER-COOLED COMPRESSOR.

Stainless Steels

THEIR POSITION IN THE U.S.A. IN 1915 AND 1940

Various aspects of metallurgy as they were in 1915 and as they are to-day are reviewed in a recent issue of "Metal Progress." Concerning stainless steels, MR. FREDERICK M. BECKET writes that in 1915 "experimental work has been conducted at various laboratories on the alloys of iron and chromium, and the high nickel-chromium alloys have been commercialised as electrical-resistance elements withstanding oxidation at high temperatures. His own work on the chromium-iron and chromium-manganese series has shown that at least 20 per cent. chromium is necessary to effect an adequate resistance to oxidation at temperatures above 980 deg. C. and an effective resistance to acid attack; however, in neither direction have experiments gone beyond exposure tests in several plants. A good market should be eventually developed."

Brearley's Achievement

Continuing, he says "most metallurgists will be pleasantly surprised by the recent achievement in England of Harry Brearley—the development and commercialisation of a cutlery alloy having noble properties and termed 'stainless steel.' It is understood that commercial production of this steel will be undertaken in America within a few months. The stainlessness seems to result from the combined effect of alloying and heat-treatment. The production of such steel on an industrial scale in itself is a great accomplishment; not only has it been necessary to develop proper casting practice, but, in addition, to master the very difficult technique of forging. The cutlery so produced is said to retain its finish, so that, despite the high cost, a ready market is expected for this steel, which will be treasured by the housewife and artisan for its stainlessness."

Coming to 1940, the writer states that developments in stainless steel since 1915 have been truly remarkable. In 1939 about 150,000 tons were produced in the United States. The austenitic 18 per cent. chromium, 8 per cent. nickel type represented the largest portion; another large part comprised the low carbon, 13 to 18 per cent. chromium type; an important tonnage included heat-resisting alloys containing 24 per cent. or more of chromium. The high-carbon cutlery steels constituted a small proportion. Evidently most attention has been devoted to the austenitic steels. To-day the early difficulties with intergranular corrosion have been eliminated by the addition of titanium or niobium. Corrosion resistance has been improved with respect to non-oxidising media by including molybdenum in the analysis. All these materials have found wide application in the process industries wherein (as in other uses) the development of adequate welding techniques has been of prime importance.

Resistance to High Temperatures

Of the low-carbon, plain-chromium steels, the type containing 25 to 30 per cent. of the element has found increasing use in structures resistant to high temperatures, especially since the addition of nitrogen has been used to inhibit grain growth in the rolled forms and to restrict grain size in castings. Such castings usually have even higher contents of chromium, and often have nickel as high as 20 per cent. Low-carbon steels containing 14 to 16 per cent. chromium, sometimes with nickel in small amounts, find growing use in turbine blades, airplane parts, and in other objects requiring the properties that heat-treatment confers.

Effect of Hydrogen on Various Steels

W. EILENDER and his collaborators, continuing their study of the effect of hydrogen on steels of different compositions, describe in a recent Paper in the "Archiv für das Eisenhüttenwesen" some new work on unalloyed and alloy steels which were melted under varying conditions of deoxidation, then artificially enriched with hydrogen, and finally their texture, hydrogen evolution and hydrogen content examined. The evolution of gas is made more difficult in unalloyed steels with rising carbon content, which is exhibited in low-C steels by the addition of increasing quantities of alloying elements. Niobium steels form an exception to this, as with an increase in the niobium content the rate of gas evolution increased, while austenitic and ferritic steels on storing gave off no gas at all. In steels with either ferritic-pearlitic or martensitic structures gas was expelled from all samples, except titanium steels, the expulsion of gas being rendered the more difficult the greater the degree of constraint in texture. The disappearance of hydrogen dissociation in the ferritic and austenitic steels was ascribed to the absence of A_3 and A_4 transformation and the resulting rearrangement in the lattice. It appears that the dissociation of hydrogen in supersaturated steels is closely associated with the transformation in phases. If the Ar transformation is far displaced to low temperatures under the action of alloys and by accelerated cooling, conditions favouring flocculation are produced, particularly if as a result of pronounced crystal segregation a corresponding dissociation of hydrogen is also initiated. Under certain conditions niobium can be utilised as a dehydrating medium. Most of the other alloying elements added contain hydrogen.

Gravity and Pressure Die-Casting

By ARTHUR STREET, B.Sc., Ph.D.

(*Continued from page* 484, *vol.* 62.)

Copper-Base Alloys

The melting point of these alloys is of the order of 1,000 deg. C. They are die-cast at red heat and the question of die life becomes of considerable importance. It is desirable not to try to cast threads in these copper-base alloys, to regard undercuts as something to be avoided if possible, and not to attempt to include cored holes less than $\frac{1}{16}$ in. diameter. The section of the die-casting should be as uniform as possible and one should avoid heavy masses of metal which would cause local overheating of the die. No attempt should be made to cast parts which consist of large flat areas of thin section because the superheating necessary to persuade the metal to fill the die would bring about porosity in the castings and burning of the mould near the runner position. If these limitations of die-casting in the copper-base alloys are borne in mind, many occasions will be found when pressure or gravity die-castings in 60/40 brass or gravity die-castings in brass or aluminium bronze can be intelligently used.

Brass Die-Castings

There are two reasons why 60/40 brass is preferred to other straight brasses as a material for die-casting. It is more ductile at high temperatures than an alpha brass and, still more important, it has the lowest melting point of the copper-zinc alloys which are useful in engineering. Brass may be either gravity or pressure die-cast but, for reasons explained later, it is the gravity die-casting process which is used for the majority of jobs. In addition to the 60/40 brass, a number of special alloys can be gravity die-cast, *e.g.*, copper-zinc-silicon alloys.

The combination of high temperature and high pressure of injection means that brass pressure die-casting is only to be recommended for certain jobs of not too elaborate design and uniform section not greater than $\frac{1}{8}$ in. In any case, its cost works out more than the cost of a hot pressing or sand casting and, consequently, brass pressure die-castings only become competitive when they can offer a closer approach to the finished article than other methods of manufacture.

The Polak type of pressure die-casting machine was originally developed to deal with the pressure casting of brass. In order to minimise the wear on the die, Polak designed the machine to inject the brass in a pasty condition, *i.e.*, below the temperature at which it is fully liquid. To do this he had to use a high pressure of the order of 2 tons per sq. in. and, additionally, in order to minimise the effect of the hot metal, he designed the machine as a "cold-chamber" type. Nowadays, the Polak machine is still used for pressure casting of brass, but the advantages of casting at high pressure and the general excellences of the machine have caused it to be used to a much greater extent for die-casting the aluminium and zinc alloys. In the die-casting foundry with which the author is connected, although most of the machines are of the Polak type, less than 5 per cent. of them are used to produce brass pressure die-castings.

Aluminium Bronze Die-Castings

This is probably the most important copper-base alloy which is die-cast. The composition is based on copper 90 per cent., aluminium 10 per cent., but in most cases additions of iron up to 3 per cent. are made, giving an increase in tensile strength. An average figure for iron content is 1.5 per cent. Owing to the fact that the alloy has to be poured in a tranquil state, pressure die-casting does not lend itself well to the fabrication of aluminium bronze, and it is the gravity die-casting process which is used. In its gravity die-cast condition, aluminium bronze has properties considerably superior to those of the alloy in the foundry cast state. Average figures are:—Tensile strength, 35 tons per sq. in.; elongation, 35 per cent. on 2 in.; Brinell hardness, 120. In addition to these useful physical properties, aluminium bronze is strongly resistant to most forms of corrosion. The weight of die-castings in this material ranges from a fraction of an ounce to 7 lbs., or more.

Cost of Pressure Die-Castings

To anyone who has not been accustomed to the use of pressure die-castings, the quantities which are required over the year have a surprising effect on the cost. This is not only because a die has to be made and paid for, but because the setting-up and the early stages of production have all to be taken into account; thus, in one zinc-base pressure die-casting which the author calls to mind, the first week's work, after the die had been set up on the machine, yielded only 700 pressure castings, the next week's work produced 1,500 castings and a later week, when all initial difficulties were overcome, resulted in over 7,000 castings. It often happens that the cost of pressure die-castings on a 5,000 basis will be two or three times that of the same die-casting worked out on a 100,000 basis.

When large quantities of the order of 100,000 pressure die-castings are required, a multiple die can with advantage be considered. This naturally leads to increased tool cost, but because several castings are produced at each shot, the cost per piece is obviously reduced. A similar procedure which is sometimes adopted is grouping a set of components into one multiple die. Thus, for instance, the case and working parts of a lock may be grouped together and the various items of a control-gear assembly may be included in the same die.

Sometimes it pays to include in one mould two or three unconnected items which are used in approximately, but not exactly, equal quantities, and it may be worth while to adopt this procedure even if it involves melting up the few surplus castings which are not required. This grouping of components into a multiple die should not be carried too far, because over-elaboration tends to increase the liability of a minor fault in one of the parts necessitating the scrapping of the whole set. Except in special cases it is wise to limit the number of different impressions per die to four; the argument of course only applies when a set of different parts are being produced from the same die.

Designing for Die-Casting

Practically any shape can be die-cast, but conjuring tricks in die-casting are expensive and unduly complicated dies are, likewise, expensive. When any component is designed for die-casting it pays all concerned to see that the part will be as easy as possible to produce, that unnecessary complications will be avoided and any features in the design which might lead to continual die breakdown are examined to see if they can be eliminated.

A die-casting is produced from two halves of a permanent mould which has to be opened and closed as rapidly as possible. Holes and recesses are produced by cores which are either included as part of one of the die blocks or, more usually, are operated by individual mechanisms. The more directions of core movements, the greater will be the expense of the die-casting. Any complexity which involves a collapsing or knock-out core, or which requires a core to be moved through the arc of a circle, or to be screwed out, will reduce the rate of output and therefore will increase the cost.

When designing for die-casting one should visualise the complete article and consider whether it can be die-cast in one piece. Just because an assembly was previously made of a couple of extruded sections, a brass pressing, a turned part and so on, there is no reason why each of those little items should be die-cast separately, and then assembled together in the old way. One should ask whether the use of die-casting can avoid the various assembling operations and produce the complete part in one well-designed entity.

It so often happens that when a designer has a job laid out and has a nice new blueprint made, he cannot bear the thought of scrapping his design and starting afresh. If a die-caster who wants to produce some of the components ventures to suggest a few alterations, he gets a very chilly reception. It is for this reason that users should consult the die-caster while the ideas are still embryonic. The designer who is really proficient in the use of die-castings will have a preliminary consultation with his die-caster and will sketch out the rough outlines of the part which is to be produced, showing where essential holes are to be cored and what localities are specially important. If the die-caster suggests alterations in design which will be in the user's interest, there is seldom any objection to such amendments in these early stages.

Cored Holes

There are two ways in which a cored hole or recess can be formed. If the recess is a large one and in line with the axis of the die, it can be formed by part of one of the die blocks. In the casting of a large gear case the main recess was formed by the moving die-block itself. The twelve fixing holes on the flange around the recess were formed by twelve core pins which were all mounted on the same mechanism, so that they could be inserted and extracted by the operation of a lever. This is the most usual way of coring small holes in pressure die-castings. In most cases it can be assumed that every direction of cored holes will need a separate operation by the die-caster, so that for reasons of economy the cored holes should be arranged to lie in as few directions as possible.

So that the core pin can be withdrawn from the solidifying casting, a taper must be provided. It is not possible to give a ruling as to the exact taper for various alloys, although rough averages are given in Table I. In addition to the problems which each particular alloy involves (for instance it will be noticed that aluminium needs much more taper than zinc alloy) each die-casting design must be considered on its merits as regards taper. For instance, a flimsy die-casting including long holes of small diameter would need more steeply tapered core pins than those in a sturdy die-casting with short holes. Similar remarks, by the way, apply to the "leave" which has to be given on faces of the mould parallel with the die axis.

Section of Die-Castings

Heavy section should be avoided for the following reasons:—

(*a*) Unduly heavy section means that the die-casting will weigh more than it need and so will cost more. Also thick sections mean slower cooling, so that the production rate will be re-

duced, which will again have an influence on the cost.

(*b*) Thick sections are unnecessary, particularly in pressure die-casting where the metal will run when it is $\frac{1}{16}$ in. or even less.

(*c*) The strength of a die-cast item will be greater than that of the same part sand-cast; consequently there is not the same need for bulk of metal.

(*d*) The use of die-casting allows the judicious inclusion of ribs, fillets and local strengthening. It is much more satisfactory to design a part so that it is strong in the localities which are highly stressed than it is to rely on sheer thickness of section throughout and hope for the best. Might it be suggested that since bridges and aeroplanes are designed in the former scientific manner, a little more attention might be paid to die-casting? The most suitable section for a pressure die-casting varies between $\frac{3}{64}$ in. and $\frac{1}{8}$ in. Gravity die-casting does not permit of very thin section being attempted and a useful average is $\frac{1}{4}$ in.

(*e*) It must be admitted that in a die-cast part of thick section, say 1 in., there is always the tendency that such a mass of metal may contain a contraction cavity. The outside skin of a die-casting chills very rapidly and if the design is such that a locality of heavy section becomes "isolated," the exterior of that section will solidify so that the metal inside will leave a small cavity as it solidifies and contracts. This trouble can, of course, be minimised by careful attention to the design of the die but generally speaking unduly heavy sections should be avoided. Particularly in pressure die-casting where solidification is rapid and indeed where events take place at a very violent speed, there is danger of porosity if the section of the part is irregular and contains thick masses of metal. In such cases the designer should relieve the heavy sections so as to get a nearer approach to uniform thickness.

A locality of thick section is generally only included in a casting in order that a hole or other recess can be machined into it. In such cases the hole should definitely be cored by the die-caster even if it involves a slight amount of trouble through the wear of that particular core pin. The author recalls many cases where small holes in aluminium alloy die-castings have been cast solely to break up heavy section and knowing full well that those particular core pins would have to be renewed after every few thousand shots.

There used to be an impression among some engineers that pressure die-castings were something like solidified sponges. Frankly, a die-casting which is full of porosity is a sign of rank bad workmanship, and the sooner that die-caster takes up some less exacting career the better for everybody concerned. If the section of a die-casting is less than $\frac{1}{16}$ in. the user should expect it to be solid. If the part does contain a chunk of metal about an inch cube there would certainly be a likelihood of a contraction cavity, but from the point of view of strength, cost, design and avoidance of porosity such a part should be amended on the lines suggested previously. In addition to the benefit of improved solidity, the part will present fewer problems from the die-casting point of view if the section be as uniform as possible.

Undercuts

When the design of a die-casting is such that a recessed feature interferes with the straight-line withdrawal of cores or the opening and closing of the die, it is said to be "undercut." The production of undercuts necessitates the manipulation or dismantling of part of the die to allow the casting to be extracted. It will be appreciated that if the whole of an inside portion including the recess had been produced by a one-piece core, the casting would solidify around the core so that it could not be withdrawn. The method of coring a curved recess is to make the core in several pieces (three in some cases), withdraw the centre part first and then collapse the other core pieces inwards.

General

(1) Lettering can be included, particularly in pressure die-casting. Because it is easier to engrave lettering into the tool, this should be raised on the die-casting. The position of the lettering should be carefully chosen so that it does not interfere with the opening and closing of the die, *i.e.*, the plane of the lettering should be at right angles to the axis of die opening.

(2) Where the die opens and closes there will be a flash which will remain as evidence of the joint line. The parting line can often be arranged to lie around the edge of the casting so that the flash can easily be trimmed away and the position will not be so noticeable.

(3) Inserts can be included in die-castings. The part to be cast-in is knurled or machined in some way so that the die-cast metal will grip on to it, thus preventing it from rotating or coming loose during service. The insert is located in the die with the machined portion projecting into the cavity, the metal then flows round this part of the insert. In addition to metals like brass and steel, other materials have been used with success as inserts, *e.g.*, plastics, fibre, compressed paper and even other die-castings.

(4) Ejector pin marks are usually visible on pressure die-castings. The ejector pins which form these marks are a necessary evil in the case of pressure die-castings as a method has to be found to remove the die-casting from one-half of the die impression while the casting is still in a soft condition. If this were not done, the casting would shrink on to the die and would have to be removed with a chisel or blowlamp. The ejector pin marks are not unsightly and can generally be arranged on an inside surface or on a face of the casting which will not be conspicuous in use.

An A.R.P. Course for the Public

Following the issue of the popular threepenny pamphlet, "Your Home as an Air Raid Shelter," of which over 700,000 copies have been sold, the Ministry of Home Security has now issued a second pamphlet called "Air Raids: What You Must Know: What You Must Do." This pamphlet is a complete "potted" A.R.P. course for the general public. It deals with such subjects as protection against bombs, behaviour during and after a raid, how to deal with incendiary bombs and war gases, and contains a simple first-aid course. It tells the householder all about the warning system, how to make repairs to his house after a raid, and contains a wealth of practical information on all these subjects. The book is fully illustrated with photographs and diagrams. It can be obtained through any newsagent, price 3d., or price 4d. post free from the Stationery Office, York House, Kingsway, London, W.C.2.

New I.B.F. Council Members

Owing to the cancellation of the annual general meeting of the Institute of British Foundrymen, at which the result of the ballot for the election of five new members of Council would normally have been announced, special arrangements for counting the ballot were made by the Executive Committee. As a result it is now announced that the following members have been elected to the Council for the period 1940-41: Mr. H. Bunting (Derby), Dr. A. B. Everest (London), Mr. J. W. Gardom (Birmingham), Mr. R. A. Miles (Manchester), and Mr. F. K. Neath, B.Sc. (Leeds).

Effect of Varying the Silicon Content of Cast Iron

(*Continued from page* 3.)

The 2.75 per cent. total carbon irons show a reduction in section sensitivity only with more than 2.00 per cent. silicon. At 2.50 per cent. silicon, these irons show a surprisingly constant hardness in the light and heavy section castings. In this series of irons, an increase in strength properties was observed as the silicon content increased from 1.50 to about 2.00 per cent. With further increase in silicon, however, the strength properties decreased.

From the strength curves, it will be seen that the tensile strength increases from about 11.2 to 17.9 tons per sq. in. as the total carbon decreases from 3.50 to 2.75 per cent. This is an increase in tensile strength of about 2 tons per sq. in. with a reduction of 0.25 per cent. total carbon from 3.50 to 2.75 per cent.

For the greatest constancy of properties of grey iron, the relationship of the total carbon and silicon may be expressed by the following equation:

Per cent. total carbon + 0.60 per cent. silicon = 4.25 per cent.

By applying this equation to each carbon series shown in Figs. 1 and 2, it will be found that the silicon-carbon relationship for minimum section sensitivity should be about as follows:

T.C. per cent.	*Si. per cent.*
3.50	1.20
3.35	1.50
3.00	2.00
2.75	2.50

Conclusions

From the data obtained in this investigation, the following conclusions may be drawn:—

(1) There exists an optimum silicon content for each carbon level to obtain the minimum section sensitivity, which is indicated by hardness values of the same order between light and heavy sections. The section sensitivity is generally in a higher hardness range for the low-silicon irons and in a lower hardness range for the high-silicon irons.

(2) The tensile strength decreases with increase of silicon in the 3.50 per cent. total carbon iron. However, it changes its response to increasing silicon as the total carbon falls to 2.75 per cent. The tensile strength does not change with increasing silicon at 3.35 and 3.00 per cent. total carbon and shows an increase with increasing silicon at 2.75 per cent. total carbon.

(3) Lowering the total carbon from 3.50 to 2.75 per cent. causes an increase in tensile strength of about 2 tons per sq. in. for each 0.25 per cent. drop in carbon. The hardness of $\frac{1}{2}$- to 2-in. thick sections increases about 25 points Brinell with each 0.25 per cent. carbon drop.

Publication Received

Transactions of the Institution of Chemical Engineers, Vol. 17. Published by the Institution, 56, Victoria Street, Westminster, London, S.W.1.

This particular volume, unlike some of the earlier ones, contains little of direct interest to the foundry industry. There is just one Paper, however—that by Dr. Vernon—on "Some Aspects of Fundamental Research on the Corrosion of Metals," which has a distinct appeal to the more academic metallurgical interests. Another Paper, too, has some interest for the mechanical side of foundry practice, and that is "Problems of Compressors and Compressed Gases in Industry," by Mr. R. L. Quertier. The format of these Transactions strongly resembles that now adopted by the Institute of British Foundrymen for its Proceedings.

Production of Pressure-Resisting and High-Duty Iron Castings

By J. L. FRANCIS, A.M.I.Mech.E.

(*Continued from page* 481, *vol.* 62.)

Pistons

Several single-acting pistons are also shown in Fig. 13, and others of a different kind in Fig. 14. In all cases these are run from the top, through gates cut in the locating print arranged so as not to come opposite the gudgeon-pin bosses. The pistons with two diameters have the large part in the top. Metal thickness in all the examples shown is slight, and usually the moulds are poured from hand shanks.

Ring grooves and gudgeon-pin holes must in all cases be free from porosity, and the sloping shoulders of the stemmed pistons are expected to give a clean surface when machined. The shoulder is a likely place in which to find a defect; the abrupt change of diameter tends to check the metal flow and act similarly to a skim-gate. Therefore, unless the iron is hot and lively, dirt may be left behind.

Bodies and Casings

Compressor bodies and casings are made in a large range of types and sizes. A rotary cas-

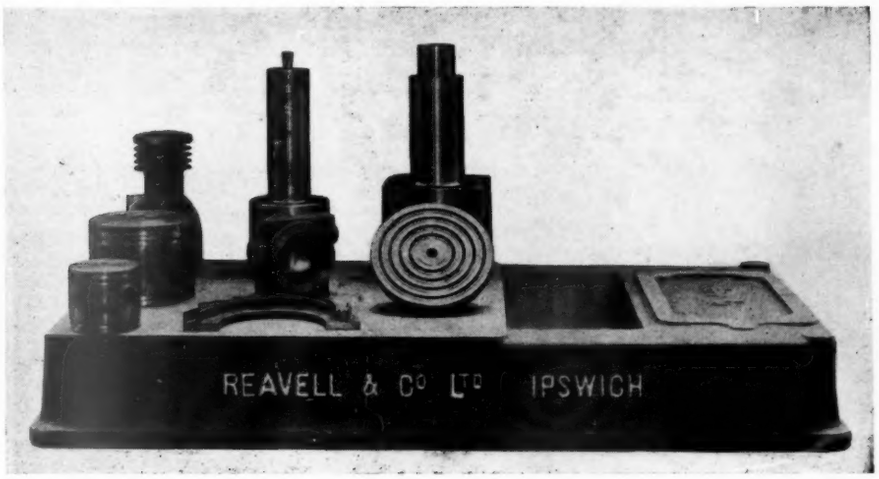


FIG. 14.—BEDPLATE AND PISTONS.

ing has already been featured in Fig. 4. They are cast with the feet in the drag; two down-runners connect with gates cut from the joint to enter the flange at each end. Risers are taken off from the flange at both ends, on top, and whistlers are cut through above each boss. The casing illustrated is air-cooled, but a water-cooled jacketed type is also made.

Some unusual features occur in the quadruplex type casing of Fig. 15; four radial cylinders form an integral part of the casting, and these are surrounded by air and water spaces as in the sectional diagram, Fig. 16. It is moulded and cast in the horizontal position, the face seen in Fig. 15 being at the top. Runners enter at the bottom of the suction facing mid-way between the two cylinder bores seen on the right, and a riser is taken off the top face. Two dummy risers are attached, one to each of the feet in the cope. Thirty-eight cores are contained in the completed mould, and the particular casing illustrated weighs 16 cwts.

A double-bore compressor body is represented by Fig. 17, with coolers as part of the casting, whilst sectional diagram Fig. 18 shows a three-cylinder body with vertical intercooler as a separate casting. These bodies are moulded on a machine of the jar-ram, roll-over and draw type. They are moulded and cast with the bores horizontal, the runners being cut on the joint at the bottom of the crankcase and two risers attached to the cooler or jacket above the bores.

Where bodies have a wall of metal common to two bores, open-grained metal is likely to appear at this juncture. Small densener strips built into the cylinder cores, so as to come adjacent to the place in question, will prevent its occurrence. In some cases the design calls for the fitting of wet or dry liners, and here the problem of soundness is not so acute.

Bedplates and Standards

Bedplates also vary greatly in size and design; the one depicted in Fig. 14 is a simple sole-plate to take the compressor and motor. That in Fig. 19 has to contain oil and has cast-boss a solid cast-iron densener, with plenty of taper, is employed to ensure a close-grained bore and sound metal in which to cut the key-way.

Machine-Moulded Castings

Many of the small castings shown in Fig. 2 are made on moulding machines. Amongst these are the single-bore and double-bore compressor bodies with cooling fins, also the air-cooled casings for small rotary compressors. The little valve bodies, too, are machine-moulded. Plate valve seats and guards are produced on a squeezer machine. These also are shown in Figs. 2 and 13. A good example of the larger plate valve seating appears poised on top of the bedplate in Fig. 14. As can be seen, the castings are shallow and therefore suited to moulding by pressure.

The concentric rings forming the seatings for the plate valves must machine up without the slightest speck or defect, otherwise they are rejected, since high-pressure air would leak past the valves. Then, too, the annular spaces between the seatings require to be true and smooth, so as to offer a minimum frictional resistance to air flow. Machining allowances are so small that the castings must be exact to pattern. An oil-bonded facing sand of fine grain size is used in order to get the small projections forming the air spaces to stand up whilst the mould is lifted from the pattern. Slots are provided in the pattern plates to coincide with those of the pattern, so that, as the mould rises from the plate, metal fingers

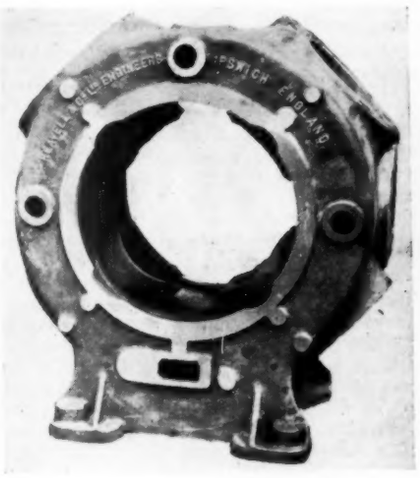


FIG. 15.—QUADRUPLEX CASING.

in bearings for the crankshaft, similar to the one shown sectionally in Fig. 20. It weighs 17 cwts., and to ensure a sound base, which is cast upwards, a flow-off gate is used.

The standard seen in the same photograph weighs 16 cwts.; it is moulded and cast horizontally. Good surfaces are required on the crosshead guides. Metal enters the mould from a gate at the end of the lower flange, the riser coming off the flange at the top. Strains set up during cooling are liable to cause cracking; thus the practice is to break the main core irons at a suitable interval after the job is cast.

Flywheels

Here again divers kinds are necessary. The one shown in Fig. 21 is one of the largest, weighing about 20 cwts. Nearly all the pulleys and flywheels are of the disc or plate type, and the heavy ones are run with a number of comparatively small runners spaced equidistantly on the plate, and fed on the rim. On the wheel illustrated there is no boss, merely a facing for the coupling. For designs carrying a heavy follow through to support the thin walls of sand until clear of the pattern; the device in action gives the converse effect of the usual application of the stripping plate.

General Principles

A few specific examples of castings have been taken and the production methods which have yielded soundness and satisfaction have been briefly indicated. Although concerned with individual items, some of the points discussed may prove helpful in other cases. Those mentioned form part only of the large number of diversified types, sizes, weights and designs needed in the construction of the extensive range of compressors made. Many other different castings offering equally difficult and interesting problems could have been selected had space and time permitted. Instead, the remaining paragraphs will contain some principles of founding which have general application.

Defects in castings have always been a major cause of anxiety among foundrymen. Little likelihood exists of this source of worry ever

being removed, because shrinkage of liquid metal during solidification is a natural phenomenon impossible to prevent. Volume contraction during freezing, aggravated by a solidification range and non-uniform cooling, is responsible for all liquid shrinkage troubles.

Casting technique continually improves and design grows more complex, coupled with requirements of a more exacting nature. At the same time methods of inspection and testing, devised to discover defects, become increasingly rigorous and severe. When due consideration is accorded these facts, together with all the influences tending to cause defective castings, it is remarkable that the percentage of good castings is as high as it is.

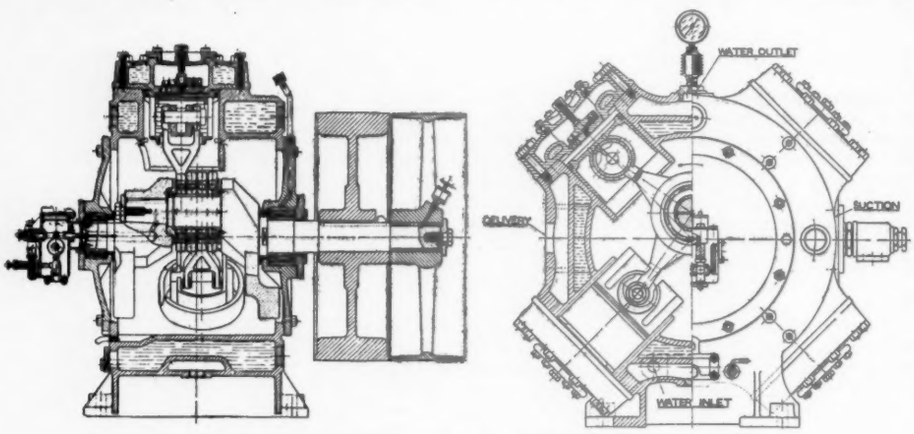


FIG. 16.—QUADRUPLEX TYPE OF CASING.

Conditions for Minimum Shrinkage Defects

In theory, a metal or alloy solidifying at a fixed temperature instantly in all parts of a mould, would form a casting perfectly free from draws, shrinks, casting strains, segregation, porosity and lack of homogeneity of structure. Unfortunately, simultaneous and instantaneous freezing is never likely to happen in practice.

Although there are a number of metals which either singly or in combination will freeze without an extended range, the temperature at which solidification takes place is not attained by all parts of a mould at the same time. The more complex the casting and the greater the variation in its sectional thickness, the larger the divergence from instantaneous solidification.

Immediately conditions depart from instantaneous solidification, those causing shrinkage and allied defects are set up. Under the circumstances, progressive solidification is the answer to the problem. Gating, running and risering should be studied from this point of view, although, of course, other considerations have weight in determining their exact positions. Dull metal is an unfailing cause of trouble; runners may set before the casting has had time to feed, resulting in the appearance of a shrink hole and, most likely, porosity. Early closing of the runner removes the ferrostatic pressure and allows evolution of the surplus gases which become trapped in the stiffening metal. Porosity so occasioned is often too small to be seen, but is disclosed by water sweating through on hydraulic testing. E. Longden[7] says: "Fluid head pressure plays a very important part in aiding soundness in any metal. If a mould contains intricate cores, then every increase in the height of the riser and gate heads will be of the greatest aid in inducing gases to pass from the core sand and away through the vents rather than bubble into the molten metal. While there is little or no direct effect on the grain structure of the metal there is no doubt that head pressure induces a higher degree of soundness in any type of mould."

Examination of many of the resources employed by foundrymen to produce sound castings discloses that their main effect is to facilitate uniform or progressive solidification.

Risers and Feeding Heads

To this end the importance of the placing of gates and runners has been stressed. It is well to remember that delayed cooling of a thin section can achieve the same ultimate effect as speeding the setting of a thick section. Thus placing the in-gates on the lightest section of a mould may be the simplest, easiest and quickest method of attaining the desired result. As a practical way of equalising the temperature of a mould the method is not as general as it well might be.

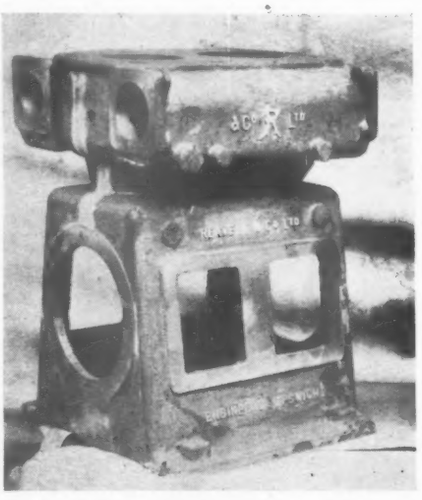


FIG. 17.—DOUBLE-BORE COMPRESSOR BODY.

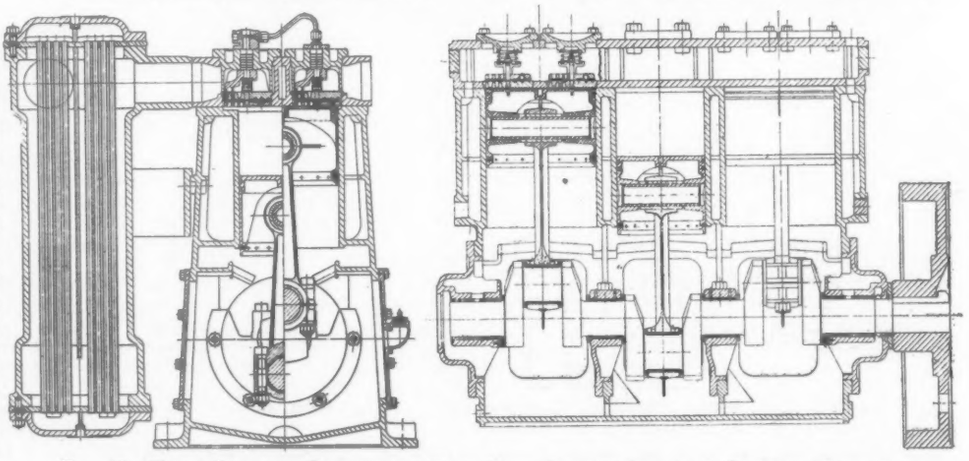


FIG. 18.—THREE-CYLINDER COMPRESSOR BODY WITH INTERCOOLER AS A SEPARATE CASTING.

Fresh problems arise with almost every different casting, and whilst experience gained from previous work is an undoubted advantage they remain to some extent individual to that particular job and part of its peculiarities.

Risers and feeding heads attached to a mould do not help simultaneous solidification. They exert a contrary effect and the efficiency with which they do it measures their degree of success. The principle underlying their use is that of progressive freezing. Providing heavy sections have the requisite accessibility they lend themselves to feeding. It is obvious that metal in a feeding head should solidify last and be fluid enough to act as a reservoir able to supply liquid metal as the solidification of the casting below it causes the metal there to recede. A pair of well-formed feeding heads, suitably positioned, can ensure soundness over quite a large volume of casting, whereas denseners applied to the same end would be awkward and of large size, introducing casting strains and the hazard of difficulty in machining. With conditions and circumstances as cited above the introduction of feeding rods into the head is useful and justified.

Rod-feeding, however, is often used where it is unnecessary and detrimental. For feeding comparatively large volumes in castings of simple form and few cores such as the rims of heavy flywheels it has a sphere of usefulness. On the other hand, high-duty irons of low total carbon content have a short freezing range. To rod-feed these may result in partially solid material from the heat getting pushed down into an important surface underneath, or the grain of the metal may be disturbed and dragged about beyond recovery. Heads of the self-feeding type are necessary in such instances, but in any case feeding with the aid of rods is an operation demanding care and skill.

Denseners

Densening is not synonymous with chilling; the latter term should be reserved for describing a means for retaining the majority, or all, of the total carbon in the combined form so as to give an iron with a mottled or white fracture. Liquid shrinkage troubles occur in many castings at places where risers and feeding cannot be applied, under conditions which are all against progressive freezing. The alternative remedy is therefore to endeavour to obtain simultaneous solidification by means of denseners, so that the metal structure is rendered uniformly close. There is another aspect of their use in which accelerated cooling at a selected spot will impart a structure of greater

denseness than ordinary mould conditions can give. Here the purpose is not so much a desire to overcome porosity due to liquid shrinkage as to confer better resistance to wear. Both purposes are accomplished at the same time in some applications; a case in point is the cylinder-bore core shown in Fig. 12. Here strip denseners are spaced out longitudinally at regular intervals. They are just discernible in the illustration.

Machining trouble arising from employment of denseners indicates that they are too heavy and drastic in action. Corners and sharp edges, where cooling is naturally accelerated, are often hard where cast in high-duty iron. A precautionary measure is to place denseners well back from such places. Denseners in the form of long strips must have their continuity interrupted at intervals to obviate buckling when they become hot. Carelessly prepared denseners can give rise to defects as a result of moisture condensing on them causing rust. Because of this hazard their use has been criticised, but with proper treatment and preparation it should not happen.

Use of Inserts

Metal lies up to a densener much better than on it; thus arrangement of them should be made bearing this fact in mind. If placed where hot metal flows past to any extent, their beneficial influence is completely destroyed. Metallic inserts act as denseners in so far as they tend to hasten cooling and minimise shrinkage. They differ, however, in that they form a part of the casting unless in a situation where removal by machining takes place subsequently. Discretion is needed especially in placing inserts, since indiscriminate use can cause the very defects they are employed to eliminate. Inserts of too heavy a section in comparison with the mass of the casting at the point where they act, are only loosely held by the solid metal, and leak badly under water pressure. Machined surfaces of importance must also be avoided or the inserts may be revealed as a discontinuity causing wearing trouble at a later stage.

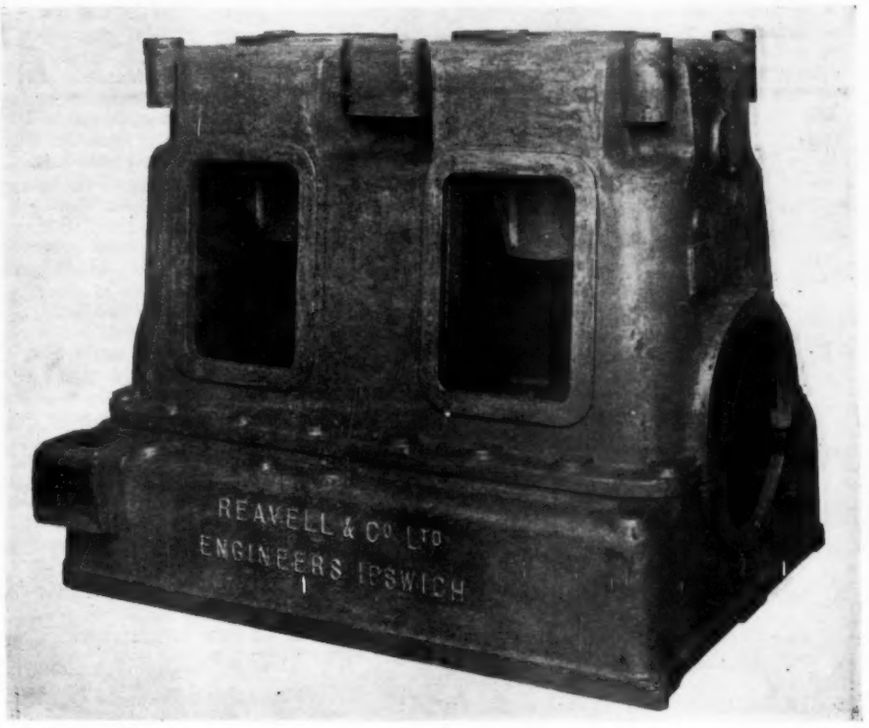


FIG. 19.—BEDPLATE DESIGNED TO CARRY CAST-IN BEARINGS.

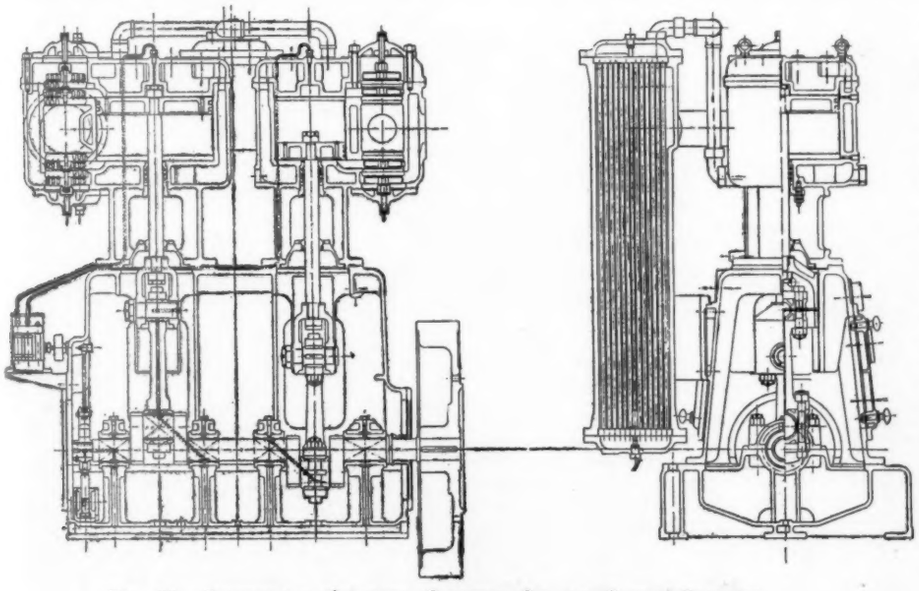


FIG. 20.—COMPRESSOR BEDPLATE CARRYING OIL AND CAST-IN BEARINGS.

Chaplets and studs used to hold cores in position must be considered as coming under this heading.

The Léonard Effect

Any factor tending to maintain metal fluid in a mould at various odd places, after the bulk has become solid, is a potential source of defects. One such factor arises when portions of the mould become excessively heated, forming "hot spots." Sand walls of little thickness may separate two heavier walls of metal, and small cores and projections are often nearly completely surrounded when the mould is cast. Prolonged passage of hot metal past a given point can have the same effect of raising the sand to a temperature approaching that of the iron itself.

Once part of the sand forming a mould or core has become so heated it not only greatly retards cooling in the metal adjacent, but most likely itself evolves gas which, finding no other exit, remains trapped in the casting. The sponginess, porosity or definite holes revealed on machining are due entirely to the sequence of events forming the "hot spot," which has also been termed the "Léonard effect."

Replacement of the sand by a densener, at the point where the hot spot occurs, removes the cause of the trouble. Ribs and webs, where they adjoin the body of a casting, often mark an area of porosity generally ascribed to drawing away of the liquid metal. When the cross-sections involved are disproportionate the cause mentioned may be correct, but the defect occurs where sections are uniform and not excessive. At rib junctures there invariably exists a wedge of sand heated from several sides and, in consequence, more fiercely. Avoidance of the rib or more rapid cooling at the junction eliminates the sponginess.

Another instance of the Léonard effect occurs where two cylinder bores come close to each other. It is also developed by moulding castings such as liners or bushes too near to one another in the same box. An unsuspected cause of the defect follows the placing of a down-sprue too near the casting. In all these cases the sand may be heated strongly enough to retard cooling, and evolve gas which is forced into the metal during solidification. The use of a very open sand and ample venting at these congested places greatly assists to overcome the trouble.

Flanged castings as illustrated in Fig. 22 often weep, under hydraulic test, at the radius under the flange, especially if the recess made to take the bolt heads cuts into the radius. A densener applied as shown is a sure remedy, or a well-dried and well-vented loam cake will prove effective. Thick masses of metal, resulting from abrupt sectional changes, enclosing thin parts of sand mould or cores, greatly aggravate trouble under this heading.

Design of Castings

A number of the methods and devices utilised by founders to overcome and avoid defective castings have been outlined. Much towards attainment of success is possible by these or similar means, but badly-designed castings, from the founding viewpoint, are a serious handicap and increase the cost of production even if they can be made sound in spite of the hazards involved.

Often a modification to the pattern which

has no effect whatever on the utility of the casting will greatly increase the chances of obtaining a sound casting and dispense with much trouble and scheming in the foundry. Neither simultaneous nor progressive solidification can prevent gas present in the liquid metal from coming off as cooling takes place, but they do ensure that no collection of it remains trapped at a spot where the metal has remained liquid.

If a thickened section is liable to contain a hidden defect, it may be not stronger but weaker than the other parts of the casting. In any case it is not proportionately stronger be-

FIG. 21.—FLYWHEEL WEIGHING ABOUT 20 CWTS.

cause cooling is retarded, with consequent increase in grain and graphite size and quantity of the latter. These influences offset the theoretical benefits shown from the calculations of the draughtsman who thickens sections to give a greater factor of safety.

Warping of castings can also be attributed to extremes of section thickness. Indeed, the stresses so imposed by differential cooling become so large occasionally as to cause severing or cracking of the parts. Hence design as

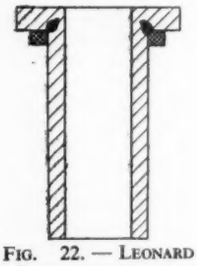


FIG. 22. — LEONARD DEFECT IN FLANGED CASTING.

applied to sectional thicknesses, changes, and the radius of fillets is of the utmost importance apart from considerations of ease and economy of production.

Coring is also a subject not always fully understood or appreciated by the designing staff. All holes and spaces in castings have to be formed by sand cores or equivalent projections from the mould surface. Wherever a core is used provision must be made to hold it securely in place, vents must be taken off from it to outside the mould, and a means found for extracting it after the casting is made. Besides all this the manufacture of cores is a charge on the job. Therefore, although cores reduce the weight of a casting, they do not necessarily lessen its cost of production.

Re-entrant cores, by extending the surface into the heart of a casting, may set up the

(*Continued at foot of next column.*)

Temperaments of Melting Units

DISCUSSION IN BRADFORD

MR. J. BLAKISTON'S Paper on "The Temperaments of Melting Units," an abstract of which was printed in our issue of May 30, gave rise to an interesting discussion when it was presented to the West Riding of Yorkshire Branch of the Institute of British Foundrymen.

MR. A. S. WORCESTER (who opened the discussion) referred to taphole sizes for air furnaces, saying he had never seen anybody manage with one so small as 3 in. In his own experience it was usually considerably larger than that, and by the time the furnace was empty it was more often about 8 in.

MR. BLAKISTON said it was quite common practice on the slag lines, where they had the greatest wear, to have a large space, but he had Scotch bricks on the 3-in. taphole described.

MR. H. A. MACCOLL asked how modern was the development of the method of stacking the charge in the air furnace as described by Mr. Blakiston? It seemed new to the speaker.

MR. BLAKISTON said there were very wide variations in performances of air furnaces, but apparently the larger the capacity the higher was the efficiency, and especially was this so with those which had a waste-heat boiler on the end. The particular plant mentioned in the Paper was, as a matter of fact, very old indeed, and the practice itself was quite an old one.

MR. TIMBRELL asked what was the average life of the type of furnace described. How often was it re-built?

MR. BLAKISTON said the type described generally worked two or three heats per week. It was re-built about once in five years. Upkeep cost was very low.

Fuel for Air Furnaces

MR. A. E. WILSON raised questions as to the nature of fuels used. He noted that on the air furnace described no mention was made of the sulphur content of the coals used. Mr. Blakiston had also mentioned that the practice was commonly used in Brightside, and had mentioned Scottish firms, but there again the question arose as to what coal they used, for there were such wide differences in the nature of various coals. Had Mr. Blakiston any remarks to make as to the reactivity of coke in regard to size of grain, density, and the calorific action of certain minerals in it? With that arose the question of the ash in the coke. Mr. Wilson referred also to the sand mixture in the bed of the furnace described, and asked whether it was not likely to make a mixture somewhat in the nature of a "glass."

MR. BLAKISTON said the coal for the air furnace was Durham coal of 1 per cent. maximum sulphur, and it gave very good results. He did not know what coal the Scottish roll foundries used, but no doubt they adjusted their furnaces to whatever it was. In regard to coke analysis, at first he was using coke made from the Halifax seam—a very good coke, but it had some characteristics which made him go over to the Durham coal product, and he believed it was generally accepted that the Durham coke gave a better result for furnaces than any other coke in the country. It was difficult to give a coal analysis, but personally he did not favour the long fingers. They were liable to lead to irregularity. As to the mixture in the bed of the furnace, on a rotary furnace this "glass," as Mr. Wilson named it, was really beneficial.

Cupola Melting Ratios

MR. A. W. WALKER said that the author had mentioned a 10:1 ratio in melting in the cupola. The speaker had many years' experience of cupola melting, and without using any fancy designs he had worked at as high a ratio as 16:1 with success.

MR. BLAKISTON said that if one could work at a higher ratio, well and good. When ratios were lower than the suggested 10:1, one was liable to lose money. He knew of one cupola working at as high as 22:1. Every individual cupola had its own characteristics, and it was useless enunciating any hard-and-fast rule. He felt the industry might, with advantage, encourage more adequate utilisation of some of the older-fashioned melting units in line with modern scientific knowledge and ultra-modern plants.

The BRANCH-PRESIDENT (Mr. S. Carter) complimented the author on tackling a very controversial subject. Every man had definite ideas about his own cupola and his own practice in getting results from it. In the matter of coke consumption and melting ratio, efficiency was not solely related to the amount of metal melted per ton of coke consumed so much as, perhaps, to the tapping temperature of the metal at the cupola spout.

MR. BLAKISTON said a point of which every practical foundryman should never lose sight was that if he made one waster casting, he probably lost more than a day's coke saving. After all, they were in business to make money by producing good castings rather than by the process of saving coke.

MR. S. W. WISE (hon. secretary) said it had always been a moot point as to what was the correct height of the charging hole from the tuyeres. Some years ago he had made some investigations with a cupola in which nine charges were used, and excellent results had been obtained. Now, on account of structural difficulties, the cupola had to be so short that there could only be three charges, but the results had exceeded every expectation, and hotter metal was being secured than, he believed, was ever done before. As to the question of life, the lining of this cupola was still the original one put in five years ago.

MR. BLAKISTON said that bore out his contention that no hard-and-fast line could be set up, and that once conditions had been established best suited to a particular furnace, no deviation should be allowed from those conditions.

MR. MACCOLL, voicing the meeting's thanks to Mr. Blakiston, said he was in full agreement with the author when he suggested that many older-fashioned melting units could give points to some more modern notions.

(*Continued from previous column.*)

Léonard effect already mentioned. Friendly co-operation between designing, patternmaking and founding departments can prevent waste of time and misplaced effort on all sides. Foundrymen often attempt the production of a casting which they know from experience will lack freedom from defects, rather than have their skill or ability called in question. General, sympathetic consideration of the difficulties of all concerned will help tremendously to smooth the path and further mutual interests.

Finally, the writer wishes to acknowledge the permission granted by Reavell & Company, Limited, and Mr. H. A. Hartley to present this Paper. He is also indebted to his colleagues, Mr. A. F. Hammond, Mr. R. J. Bartholomew and Mr. R. Leeks, for assistance in its preparation.

REFERENCE.

[1] E. Longden, "Iron and Steel Industry," May, 1936, p. 271.

Founders' Forum

Q.—How can porosity in the bore of the mould casting sketched in Fig. 1 be overcome?

A.—The porosity being experienced in the bore of the mould casting illustrated is undoubtedly due to a liquid shrinkage defect. This is caused by non-progressive solidification. If the casting has been moulded and cast with the flange uppermost, the defect will most likely appear about one-third down the bore. If cast the reverse way up, the defect will likely be located as shown in the inquirer's sketch (not reproduced). Cast horizontally it will appear as a large patch on the top side of the bore. To ensure sound castings free from all traces of porosity, the casting should be cast vertically, with a properly designed feeding head, and run preferably from the top, with small in-gates placed around the core print, as in Fig. 1.

The dimensions of the feeding head are arrived at as follows:—The thickest section of the casting is through the flange and body diagonally (D in.). Therefore the sectional thickness of the base of the feeding head, at the point where it joins the casting proper,

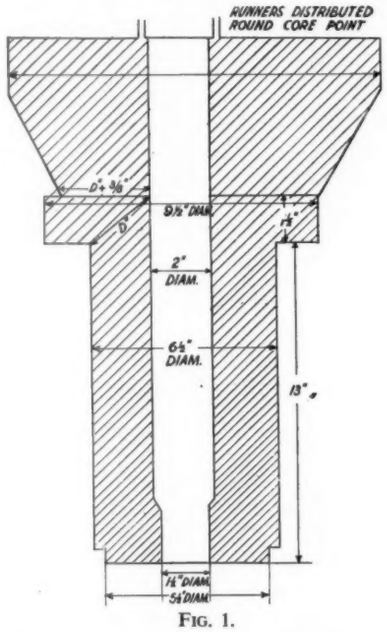


FIG. 1.

should be slightly greater (D in. + ⅜ in.). By this means the casting will solidify progressively from the bottom upwards and the liquid shrinkage will occur in the head above the top flange.

If expediency demands that the casting be cast with the flange in the bottom of the mould, the feeding head should have a similar amount of taper and be placed on the full section of the 5½ in. diameter. This method is not so reliable as the first.

In both cases hot clean metal should be poured and top running methods are essential to success. Closeness of grain and the life of the liner in operation will depend on the adoption of a suitable composition. The composition given, namely, T.C, 3.2; Si, 1.5; Mn, 0.6; S, 0.08; and P, 0.06 per cent., would be improved considerably by reducing the silicon to 1.2 to 1.3 per cent. This will give some improvement in the structure, but that will depend largely on the method of production and type of base mixture being used. At least 25 per cent. mild steel scrap should be incorporated in the charge. For improved service in moulds of this type, a nickel-chromium cast iron of medium or even rather high carbon content can be recommended. A suitable composition would be as follows:—T.C, 3.4 to 3.6; Si, 0.9 to 1.2; Mn, 0.7 to 1.0; S, 0.12 (max.); P, 0.15 (max.); Ni, 2.5 to 3.0; and Cr, 0.6 to 0.8 per cent.

Comment.—The manager of the foundry sending the query writes that while he is in full agreement with the deduction that the trouble is due to non-progressive solidification, he cannot agree that the method suggested would achieve the desired result. Probably with a larger diameter core, even with relatively thicker metal sections, the method would be successful, but in practice it is found that the small diameter core, becoming incandescent by the volume of metal surrounding it, becomes a sort of reservoir of heat and forms its own hot spot irrespective of head volume or pressure. It should be added that it is necessary to have the flange cast at the bottom. He appreciated the efforts to arrive at a solution of this problem. The contributor may be pleased to hear that since the query was sent, the writer has arrived at a satisfactory solution, and the metal used is something akin to his suggestion:—T.C, 3.5; Si, 1.2; Mn, 0.40; P, 0.14; S, 0.12; and Cr, 0.72 per cent. The metal is bordering on the mottled, but with a *loam core* the castings can be readily produced.

Catalogue Received

Welding Rods for Manganese Steel. A 12-page catalogue received from Hadfields, Limited, of East Hecla Works, Sheffield, is devoted to a description of Hadmang electrodes and welding rods. As is well known, modifications of composition in the welding rods as compared with the basic material to be welded are usual, and in this case a modicum of nickel has been introduced. However, manganese steel welding rods are not used exclusively for welding manganese steel, but are well suited for depositing this alloy on ordinary carbon steels so as to yield hard-wearing surfaces. Both coated and uncoated types are being manufactured, the latter being for use as an electrode in the metallic arc process, where direct current is used. The coated type can be used with alternating current. Detailed instructions are given for the use of these new electrodes, together with some rather striking results which have been achieved. For instance, using the oxy-acetylene process, a stick four inches high was built up by the continuous deposition of drops. Then, without further treatment, it was bent to form a ring. This brochure is available to our readers on writing to Sheffield.

(*Continued from third column.*)

High-Chromium and Nickel-Chromium Steels

The corrosion-resisting properties of this group were in agreement with anticipation, on the basis of the known influence of high chromium content. Chromium-manganese steels with molybdenum additions and austenitic nickel-chromium steel were resistant to sea water, but molybdenum-free steel of this type was attacked. The high-chromium group behaved well in contact with nitric acid.

Bearing tests (using a shaft of chromium-molybdenum steel of 590 Brinell hardness) showed very unsatisfactory results for the austenitic nickel-chromium steel. In this respect a 30 per cent. chromium cast iron was better. It is suggested that for severely stressed parts high-chromium bearings, working against a chromium-plated steel shaft, might prove satisfactory.

Light-Metal and Bronze Bearing Alloys

Corrosion tests on three aluminium-base alloys and on four copper-base bearing metals indicated that, for use under corrosive conditions, the light alloys showed adequate resistance to acetic acid only. Of the copper alloys, the aluminium bronze had the best general corrosion-resistance. With light metal bearings a very hard shaft should be used.

Corrosion-Resistant Bearing Alloys for Chemical Plant

The "Nickel Bulletin" has made the following abstract of a Paper by C. H. MEYER, which was published in "Archiv für das Eisenhüttenwesen."

Selection of materials for use as bearings in chemical plant is complicated by the combined requirement for satisfactory bearing quality, high resistance to wear, and chemical stability under corrosive attack. The experiments described in the Paper were designed to discover alloys offering such a combination of qualities.

Bearing properties were determined in an experimental machine, in which a shaft was rotated in a bearing of the material under test. A certain pressure was employed, and the shaft speed was altered in steps. The torque imposed on the bearing by the shaft was measured by counterbalance weights, and limiting conditions for reasonably satisfactory performance were determined, both with oil- and with water-lubrication.

In order to ascertain which of the materials possessed inherently satisfactory chemical properties, a preliminary series of corrosion tests was made on the materials whose bearing properties were to be tested.

The corroding media used (in each case for certain selected alloys only) included sulphuric, hydrochloric, nitric, acetic and phosphoric acid solutions, sodium hydroxide, magnesium chloride, hydrogen sulphide, and salt and fresh water.

The materials tested and the conclusions drawn with reference to their corrosion-resisting and bearing qualities are summarised below:—

Austenitic Nickel-Containing Cast Irons

A series of cast irons of the standard and modified Ni-Resist and Nicrosilal types was studied, special attention being directed to the influence of increased chromium in Ni-Resist, and the addition of molybdenum or antimony. Increase in chromium did not appreciably improve corrosion-resistance, and the influence of molybdenum was generally similar to that of chromium, although in hydrochloric acid the molybdenum addition conferred some increased stability.

In the case of antimony, the addition of 3 per cent. to an austenitic iron caused rise in hardness and a slight fall in machinability. Amounts up to 0.6 per cent. antimony improved resistance to hydrochloric acid, but higher percentages caused but little further change. Resistance to sulphuric and acetic acids was not affected by the presence of antimony. Copper had a marked effect on resistance to mineral acids and to phosphoric and acetic acids. In most cases 7 to 8 per cent. of copper appeared to give the highest degree of resistance, but in the case of sulphuric acid further improvement was obtained by increasing the copper to 15 per cent. In general, high-nickel cast irons containing no copper were less resistant to corrosion than irons of the Ni-Resist type.

In view of the fact that the Ni-Resist irons showed the highest degree of general corrosion-resistance, the bearing tests were made on this type of material and on some other high-nickel cast irons showing various types of structure. All these materials behaved satisfactorily as bearings, efficiently increasing with increased difference in hardness between shaft and bearing. Study of the influence of structure showed that reduction in graphite content did not improve bearing qualities, and that replacement of graphite by carbide had an even more adverse effect. In austenitic cast irons, a small amount of carbide is desirable, but the proportion should be strictly controlled.

(*Continued at foot of previous column.*)

Glass Technology as Applied to the Study of Vitreous Enamels*

By R. J. SLAWSON, M.Sc.TECH.

This Paper is an attempt to bring to the notice of vitreous enamellers some of the work which has been done in the field of glass technology, where it may be applied directly or indirectly to the study of enamels. Glass technology has now been studied at Sheffield University for nearly twenty-five years. A very great deal of research work has been carried out there and in other laboratories throughout the world. Much of this work has no bearing on the subject of vitreous enamelling, but a great deal of it, even if not directly applicable to enamels, gives a lead to enamellers in showing the method of approach to a subject and the type of results to be expected.

It is proposed to review very briefly some of the branches of the subject and to indicate, where possible, the connection between glass and enamel technology. An effort will be made to avoid, as far as possible, taking sides in any matters of controversy, and in some cases the mere mention that other theories exist must suffice.

Definition of Glass

It is very difficult to find a really strict definition of a glass. There is, however, an old definition which runs as follows: "A glass is a hard, brittle, amorphous substance, breaking with a conchoidal fracture and having the property usually of transparency, though it may be translucent or even opaque. It is formed by the fusion together of acidic and basic materials and subsequent rapid cooling."

This definition excludes, however, the organic resins and other plastics which are now recognised as true glasses. It is considered that any material which, on being cooled rapidly from the molten condition, shows no sudden change from liquid to solid, but gradually sets, is a glass.

Nature of Glass

There have been a number of theories as to the physical nature of glass, and one which gained considerable prominence was that glass is a supercooled liquid—certainly in some of its properties it behaves as such—but it is now generally regarded almost as a fourth state of matter which, for most practical purposes, is a solid. Some of the properties of glass which are not those of a normal solid are, however, of interest in considering the behaviour of enamels.

Glass subjected to mechanical strain for extended periods can sometimes exhibit strange phenomena. It may, if the strain be large enough, eventually break, after standing the strain for hours, days, and sometimes even years. It may, on the other hand, become semi-permanently deformed; when the stress is removed, the deformation due to it partially persists and disappears only after some time.

The somewhat similar thermal effect of "after-contraction" will be familiar to all who have, in Fourth Form physics, had to determine the fixed points of a thermometer. This property of delayed contraction after thermal expansion is exhibited to varying degrees by most glasses and at one time caused great difficulty in the construction of accurate glass thermometers. Much research was done on the subject, and several glasses were developed which possessed this property to an extremely small degree. Notable among these are Jena 59111, Kew glass and Verre Dur. The main factor in the production of such glasses is the use of one alkali only—preferably potash.

These rather peculiar properties of glass offer some elucidation of the phenomenon of "delayed fishscaling" in sheet-iron ground coat and of delayed failure in general. In each case of delayed failure a state of strain exists either between the enamel layer and the metal base or in the enamel itself—for the present case the cause of this strain is of no particular concern. If the resulting stress is great enough, the enamel may fail after a time purely by the delayed fracture effect. On the other hand, even if the original stress would never cause failure, it may be increased to such an extent that failure occurs by the effect of after-contraction. (After-contraction has been known to continue for as long as five years.)

Delayed fracture seems an inherent quality of glass, it is the "nature of the beast," but "after-contraction," as previously mentioned, depends largely on the composition of the glass, and it would be interesting if it could be demonstrated that ground coats, for instance, showed less tendency to delayed fishscale if the only alkali present was potash. Fishscaling is also more likely to occur if the plates are stored in a damp atmosphere—this is often taken as indicating that weathering is a contributory cause of the defect. This is not necessarily true, as it is a well-known fact that the cracks in glass travel much faster if the glass be damp.

Constitution of Glass

There are many theories which attempt to give a microscopic picture of the ultimate atomic constitution of glass. It is not intended to do more than mention very briefly indeed the main points of what is, perhaps, the most generally accepted theory and to indicate some of the conclusions which may be drawn from it.

The random network theory of glass constitution has been reached by systematic X-ray diffraction measurements by many workers. It postulates that a glass consists essentially of an arrangement of atomic cells of some glass-forming material arranged according to certain laws, but in such a manner that the configuration of atoms is not repeated in a regular manner as in the case of crystals. Any other atoms present are merely embedded in this network and are not chemically combined in the general sense of the term.

The strict condition that a substance is capable of forming a glass is that it is capable of forming an extended three-dimensional network lacking periodicity and symmetry and, in order that the glass may be stable, with an energy content comparable with that of the corresponding crystal.

The conditions that must be satisfied if an oxide of the element A is to form this network are as follow:—

(1) An O atom must be linked to not more than two atoms of A. (Fig. 1.)

(2) The number of O atoms about an A atom must be small.

(3) The oxygen polyhedra about A must be capable of sharing corners only with each other. (Fig. 2.)

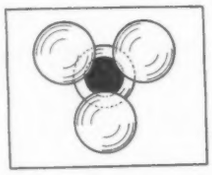


FIG. 1.—DIAGRAM REPRESENTING UNIT ATOMIC CELL OF SiO_2. LARGE SPHERES: OXYGEN ATOMS. SMALL SPHERE: SILICON ATOM.

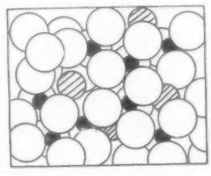


FIG. 2.—DIAGRAM SHOWING RANDOM NETWORK OF SYSTEM SiO_2-Na_2O. LARGE SPHERES: OXYGEN ATOMS. SMALLER SHADED SPHERES: SODIUM ATOMS. SMALL BLACK SPHERES: SILICON ATOMS.

(4) At least three such corners must be shared in this way.

This limits the number of possible glass-forming oxides to 11. (Table I.)

TABLE I.—*Oxides Theoretically Able to Form Glasses.*

(*a*) Glasses known to exist:—B_2O_3, SiO_2, GeO_2, As_2O_5, P_2O_5, As_2O_3.

(*b*) Some evidence that glasses exist:—Sb_2O_3, V_2O_5.

(*c*) No evidence: P_2O_3, Sb_2O_5, Ta_2O_5.

In order to get a little clearer picture of the difference between crystal and glass, one can take an analogy on a much larger scale, by considering the atomic cells as bricks. If these bricks are laid down in a regular manner then a crystal results; if they are just dumped in a heap, a glass forms. The analogy is not very close; it would be closer if tetrahedral bricks were used and so arranged that each one rested its corners on those of four others, but that is an unnecessary complication. Now in the case of an oxide which is incapable of forming a glass, consider the atomic bricks as spheres; however these are dumped, a slight disturbance will result in their taking up a regular arrangement, that is, the oxide will crystallise.

The conclusion is reached that, in order that a certain material will form a glass on melting and subsequent cooling, it must contain a fairly high percentage of one or more of those six known glass-forming oxides.

Devitrification, that is, reversion from the glassy to the crystalline state, does not, in its milder forms, worry the enameller very much. This is due to the rapid cooling which enamels undergo both after melting the frit and after firing the enamel. Enamel glasses with a tendency to devitrification should, however, be avoided owing to the danger of producing bad surfaces, particularly on cast iron where the cooling is somewhat slower.

* Paper read before a joint meeting of the Southern Section of the Institute of Vitreous Enamellers and the Society of Glass Technologists, Mr. G. H. Abbot presiding.

The comparative freedom from devitrification enjoyed by the enameller is not, in one way at least, an unmixed blessing, for the enameller is unable by normal methods at any rate to obtain the decorative finishes which the potter can produce by controlled devitrification in his glazes.

PHYSICAL PROPERTIES

Expansion

The most important physical property as far as the enameller is concerned is thermal expansion. Unless the thermal expansion of the enamel glass (taking into account the mill additions) is approximately equal to that of the metal, the two will not adhere together permanently.

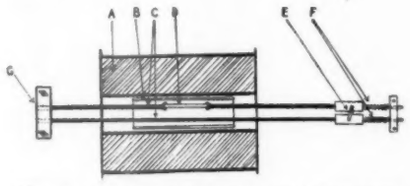


FIG. 3.—SECTIONAL DIAGRAM OF APPARATUS FOR DETERMINATION OF THERMAL EXPANSION.

A, electric tube furnace. B, copper tube to equalise temperature. C, silica rods. D, specimen. E, mirror. F, loading springs. G, clamp.

There are several ways of measuring the expansion of glass, the most usual in this country being that admirably described by Mr. Abbott in his recent Paper entitled "Investigation and Modern Ideas on Enamel Control."* In this method the expansion of a rod of glass is compared with that of fused silica from room temperature up to the softening point of the glass (Fig. 3). If the specimen has been carefully annealed and the rate of heating is sufficiently slow, the results plotted on a graph will give a curve of the type shown in Fig. 4.

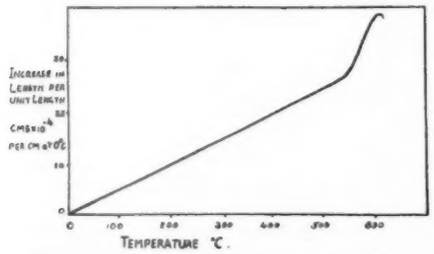


FIG. 4.—GENERAL FORM OF EXPANSION CURVE FOR GLASS.

This demonstrates another divergence between the properties of glass and other solids, which mostly give approximately straight lines which are unaltered by the rate of heating. The faster the glass is heated the nearer the curve approaches a straight line.

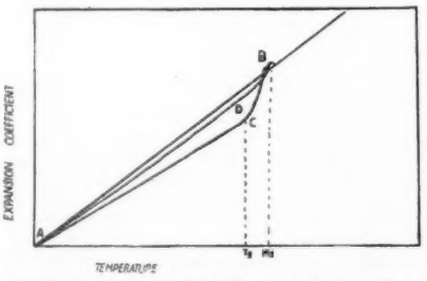


FIG. 5.—CURVES REPRESENTING EXPANSION OF METAL AND GLASS (EXAGGERATED).

* Proc. I.V.E., vol. V (1939), pp. 159-191.

The sudden increase in thermal expansion of glass at a certain temperature, the transformation point, was noted by Peters and Cragoe in 1920 and it was found that above this transformation point glasses have the property of plastic flow. The higher the temperature, the smaller the force required to cause deformation, until at the point where the curve bends over, the force exerted by the loading spring in the apparatus is sufficient to deform the rod under test.

The range between the transformation point and the softening point (Tg and Mg) is known as the annealing range, and it is in this part of the cooling curve that great care must be taken in glassmaking in order that any strain caused by differential cooling between the inner and outer layers of glass may be released by plastic flow in the body of the glass.

The problem of annealing, in this sense, does not apply to enamelling, nor does the consideration of the expansion curve obtained by very slow heating. The enameller is interested only in the total expansion of the enamel between the softening point and room temperature, and as his rate of cooling is rapid the expansion curve under these conditions will be somewhere near a straight line and this line must be approximately the same as that for the metal base. In fact, if the cooling of an enamelled piece were carried out in a similar manner to that of a glass article, it is quite possible that the strain resulting between the enamel and metal layers would be greater than it would be if the piece were cooled in the ordinary way.

Fig. 5 shows an exaggerated set of curves representing the expansion of the metal (AB), the expansion of the glass when heated, or cooled, quickly (ADB), and the expansion of the glass when heated or cooled slowly (ACB). Tg is the transformation point and Mg the softening point. Now suppose that the temperature of the metal and enamel is about Mg when the piece is removed from the furnace; if the temperature drops rapidly the enamel and the metal will contract at roughly the same rate right through the cooling process, and the final result will be that the enamel and iron, having started equal in size and having contracted equally, will still be equal and thus no strain will exist. On the other hand, if the cooling is slow, the enamel will tend to follow the curve ACB. Above Tg any tendency to difference in size between the enamel and the metal will be removed by plastic flow; one thus has the enamel and iron equal in size at Tg and contracting at different rates—the final sizes of the two will differ, and a state of strain will exist.

Viscosity

The viscosity of enamels at varying temperatures is of interest as it determines to a large extent the firing temperature. It is obviously necessary in firing an enamel to reach such a temperature that the viscosity is low enough to enable the enamel to flow out to a smooth surface. It has been found in glassworks' practice that similar operations on different glasses should be carried out at approximately the same viscosity. The working limits for glass-forming, for instance, are given as $10^{-2.5}$ to $10^{+6.5}$ poises. Similarly, it may be inferred that the viscosity of various enamels at their minimum firing temperatures is roughly a constant value.

There are several methods available for the determination of the viscosity of glass. The method which has been used for the determination of the medium values of viscosity is a direct development of the rotating cylinder type of viscometer. A cylinder of hard burnt sillimanite is rotated inside a container of the same material while the space between the two is full of molten glass. The whole is enclosed in an electric furnace and the viscosity is measured by the force required to rotate the cylinder at a constant speed. There are, however, one or two sources of error in this method; very small errors in the adjustment of the apparatus and in the measurement of the size of the cylinder are greatly magnified in the final result.

For very low values of viscosity the falling-sphere method may be used. In this method the viscosity is deduced from the rate of fall of a small platinum sphere through the molten glass contained in a suitable furnace. The rate of fall is measured by taking X-ray photographs of the furnace at regular intervals or by the induction effect of the sphere on coils surrounding the furnace.

For very high values of viscosity, *i.e.*, at temperatures in the annealing range, Stott Irvine and Turner measured values up to 10^{17} poises by determining the extension rate of a loaded glass rod.

An interesting method for determining comparative viscosities which is very useful for prolonged experiments on one particular glass depends on the measurement of the thickness of the glass film adhering to a platinum wire withdrawn from the molten glass at a constant rate. Absolute values for elasticity and mechanical strength of glass are very difficult to obtain as the value depends enormously on the size of the specimen tested. Degree of annealing also affects the mechanical properties very markedly.

(*To be continued.*)

Strength of Vitreous-Enamelled Sheet

To what extent does vitreous enamel strengthen the sheet-steel product? This is a question which D. R. GOETCHIUS (Ferro Enamel Corporation) proceeds to answer in a recent issue of "The Enamelist" (Cleveland, Ohio). Admitting that the great stiffening effect of vitreous enamel on light-gauge kitchenware is well known, he points out, however, that few quantitative data are available. Andrews and Dietterle had shown (Journal Am. Cer. Soc., 23-29, 1940) that heavier applications of enamel on 26-gauge stock nearly tripled the resisting force of the specimen to cross-bend while even light applications nearly doubled their resisting force. Heavier gauges were less affected.

Better to answer the question, continues the writer, tensile strength specimens were made of standard enamelling stock of 8, 10, 12 and 14 gauges. The test-pieces were cut to obtain samples with the grain both transverse and longitudinal to the direction of stress application. These pieces were then pickled and enamelled with one ground coat and one cover coat, giving an average enamel thickness of 0.011 in. The unenamelled pieces were pulled to failure, noting yield points, ultimate strength, and elongation. The enamelled pieces were pulled until enamel failure occurred. Elongation was then measured at this point. No attempt was made to find the ultimate strength of the enamelled stock.

Examination of the data on unenamelled stock shows the effect of grain direction on yield point. Grain transverse to the direction of tensile stress *raises the yield point*, the effect being slight at the lighter gauges and becoming more pronounced at the heavier gauges. The difference in yield points expressed in pounds per sq. in. between the longitudinal and transverse grain for 14 gauge was 360, for 12 gauge 1,430, and for 10 gauge 3,590 lbs. per sq. in. By error both 8-gauge unenamelled test-pieces were of transverse grain, so no difference could be recorded. However, it will be noted that failure of the enamelled transverse piece was much

(*Continued on page* 14.)

The Week's News in Brief

Trade Talk

THE AUTUMN MEETING of the Institute of Metals has been provisionally fixed for Wednesday, September 18. The place and time will be announced later.

STAFF AND WORKPEOPLE of Hale & Hale (Tipton), Limited, malleable-iron founders, of Dudley Port, Tipton, have endowed a cot in the Children's Ward of the Guest Hospital, Tipton.

THE PRESIDENT (Mr. R. G. Crittall) and other office-bearers of the Institution of Heating and Ventilating Engineers have been asked to continue in office for the duration of the war.

DIFFICULTIES are arising from the use of wrapping papers from which old addresses have not been removed. The railways and road transport companies emphasise the desirability of despatchers of parcels removing or obliterating all old addresses from papers used as wrappings.

THE PARTNERSHIP between Messrs. Douglas John Holmes and Harold George Blanchard, carrying on business as ironfounders at Stamp End, Lincoln, under the style of Holmes & Blanchard, has been dissolved by mutual consent. Debts should be paid, and claims against the firm submitted, to Whittle & Ward, accountants, 10, Guildhall Street, Lincoln.

THE RE-USE of packages formerly non-returnable has caused a great increase in the volume of the "returned empty" traffic on the railways. It will greatly assist traders to obtain the maximum use of the packages, and will obviate difficulties at goods stations arising from accumulations of empties awaiting delivery, if firms will accept delivery of returned empties throughout the day from Monday to Friday, and also on Saturday mornings.

DISCUSSION in the Peruvian Congress over the establishment of a steel industry in Peru continues. Some interests and members of Congress favour the establishment of the industry in the Chimboto district, while others favour the Callao district as the site. It is felt if a steel industry is to be established in Peru that it must be designed to produce products for export and sale abroad because of the small national consumption and, at least at first, it would have to be financed with public funds. There are those who feel that because of the heavy capital investment necessary and the fact that the steel industry depends essentially upon volume production it would not be possible to develop a Peruvian steel industry.

COMPLAINTS have recently been made of machine tools being held up at the docks as a consequence of formalities of import and the levying of duties. In order that machine tools essential for the munitions and other essential industries should be brought into practical operation at the earliest possible moment after arriving in this country, the Treasury has granted licences whereby most of the machine tools now being imported are admitted free of duty. In addition, the machinery for the issuance of these licences has been made speedier in its operation by the issue of documents covering a series of importations, thus avoiding the necessity for obtaining an individual licence for each machine tool imported.

THE MINISTER OF HOME SECURITY has made an Order requiring drivers of motor vehicles who leave their vehicles unattended to take steps to render them temporarily incapable of being driven away. This order should be brought to the notice of the works' lorry drivers. A vehicle is regarded as unattended unless there is a person of 14 years of age or over in attendance upon it, either in the vehicle or in the immediate vicinity and within sight of it. The Order involves an amendment to the instructions which have been issued in regard to traffic on an air-raid warning. Drivers are at present advised to leave their cars unlocked if they leave them to take shelter. In future it will be obligatory under the Order to lock any vehicle which is capable of being locked, or otherwise to immobilise it.

New Company

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

E. H. Lancaster (Piston Rings), Limited—Capital £1,500. Manufacturers of piston rings for marine and other purposes, etc. Subscriber: V. K. Hoar, 30, Wordsworth Road, Wallington, Surrey.

Personal

PROF. ALBERT MARCEL PORTEVIN has been elected an honorary member of the Institute of Metals.

LORD DUDLEY G. GORDON, D.S.O., Mr. A. J. Grant, Mr. A. C. Hartley, and Mr. B. W. Pendred have been elected to the Council of the Institution of Mechanical Engineers.

MR. JOHN ROLLIN, joint managing director of John Vessey & Sons, Limited, Brunswick Steelworks, Sheffield, and president of the Crucible Steel Makers' Association, will shortly complete 50 years with the firm.

MR. DAVID MCLAIN was the doyen of those present at a dinner given in honour of 25 veterans of the foundry industry by the Wisconsin Chapter of the American Foundrymen's Association. He has 67 years service without a break. He was born in Belfast 77 years ago.

CAPTAIN TOM SHANKS, who is reported to be a prisoner of war in Germany, is the eldest son of ex-Provost J. K. Shanks, of Denny, and was works manager and a director of Cruikshank & Company, Limited, Denny Iron Works. He is a life member of the Institute of British Foundrymen.

LT.-COL. J. H. M. GREENLY, sent out by the Government to Canada and the United States last autumn to set up a purchasing organisation in each country, has returned to England, having completed his task. The Government have released him from his appointment of Controller-General of the British Supply Board in Canada and the United States of America with a view to his taking up other work. Col. Greenly is chairman of Babcock & Wilcox, Limited.

MAJOR GEORGE WHITEHEAD, a director of the Whitehead Iron & Steel Company, Limited, Limited, has been missing since the evacuation from Dunkirk. Shareholders of the company were told at the annual meeting last week that Major Whitehead joined his regiment on the outbreak of hostilities and had been overseas with the B.E.F. from the early days of the war. A complete absence of any news of him since the epic of Dunkirk left them with grave doubts as to his safety. He might, however, be a prisoner of war in Germany.

PAPER CONSERVATION AND THE EDITORIAL INDEX

The editorial index for Volume 62 (January to June, 1940) is almost completed. Readers who wish to receive a copy are requested to apply to the Publisher of the Journal, 3, Amersham Road, High Wycombe, Bucks, without delay. Owing to need for conservation of paper, the index will not be sent out, as hitherto, with every copy of the Journal.

Reports and Dividends

Vosper, Limited—Interim dividend of 5 per cent.

Mirrlees, Bickerton & Day, Limited—Dividend of 6 per cent.

W. & T. Avery, Limited—Final ordinary dividend of 10 per cent., making 15 per cent. for the year to March 31.

Anderston Foundry Company, Limited—Net profit for the year to March 31, £8,079; brought in, £6,556; dividend of 7½ per cent.; carried forward, £10,378.

John Summers & Sons, Limited—Final dividend of 4½ per cent. on the "A" ordinary stock, making 8½ per cent. for the year, and 3½ per cent. on the "B" ordinary, making 4½ per cent.

Edgar Allen & Company, Limited—Net profit for the year ended March 31, after providing for £125,000 taxation, £83,570; brought in, £37,673; dividend on the cumulative preference shares, £9,750; reserve against investment in subsidiary company now in enemy-controlled territory, £25,000; dividend on the ordinary shares of 12½ per cent., £22,445; to general reserve, £20,000; staff pensions, £5,000; carried forward, £39,049.

Obituary

MR. A. H. CARNT, a director of Peter Brotherhood, Limited, engineers and ironfounders, of Peterborough, has died, following injuries received in a road accident.

MR. GEORGE HENRY HUMPHRAY DARNBROUGH, of M. Darnbrough & Sons, Limited, brassfounders and coppersmiths, Dewsbury, has died, aged 80. He was the youngest and last surviving son of the founder of the undertaking.

THE DEATH has occurred of Major J. H. Cartland, formerly chairman of James Cartland & Son, Limited, brassfounders, of Small Heath, Birmingham. His grandfather was the founder of the company.

ALDERMAN FRANCIS HAROLD TURNBULL, J.P., O.B.E., of Cardiff, a well-known figure in the South Wales foundry trade, has died at the age of 59. He was chairman and managing director of Edward Curran & Company, Limited, of Cardiff, and a director of the Cardiff Foundry and Engineering Company, Limited. The Cardiff Foundry was one of the earliest plants to be mechanised. In 1921 Mr. Curran was the Lord Mayor of Cardiff, and in recognition of his year of office Pope Pius XI conferred on him the Papal Knighthood of Knight Commander of St. Gregory the Great. He served on many of the city council's committees.

Will

MOORWOOD, H. S., of Sheffield, director of Hedley Moorwood & Company, Limited, engineers, etc. **£2,166**

Forthcoming Event

Institute of Vitreous Enamellers

JULY 9.

Extraordinary Meeting:—To consider an alteration of the Articles of Association, at the Birmingham Chamber of Commerce, at 2 p.m.

Strength of Vitreous-Enamelled Sheet

(Continued from page 13.)

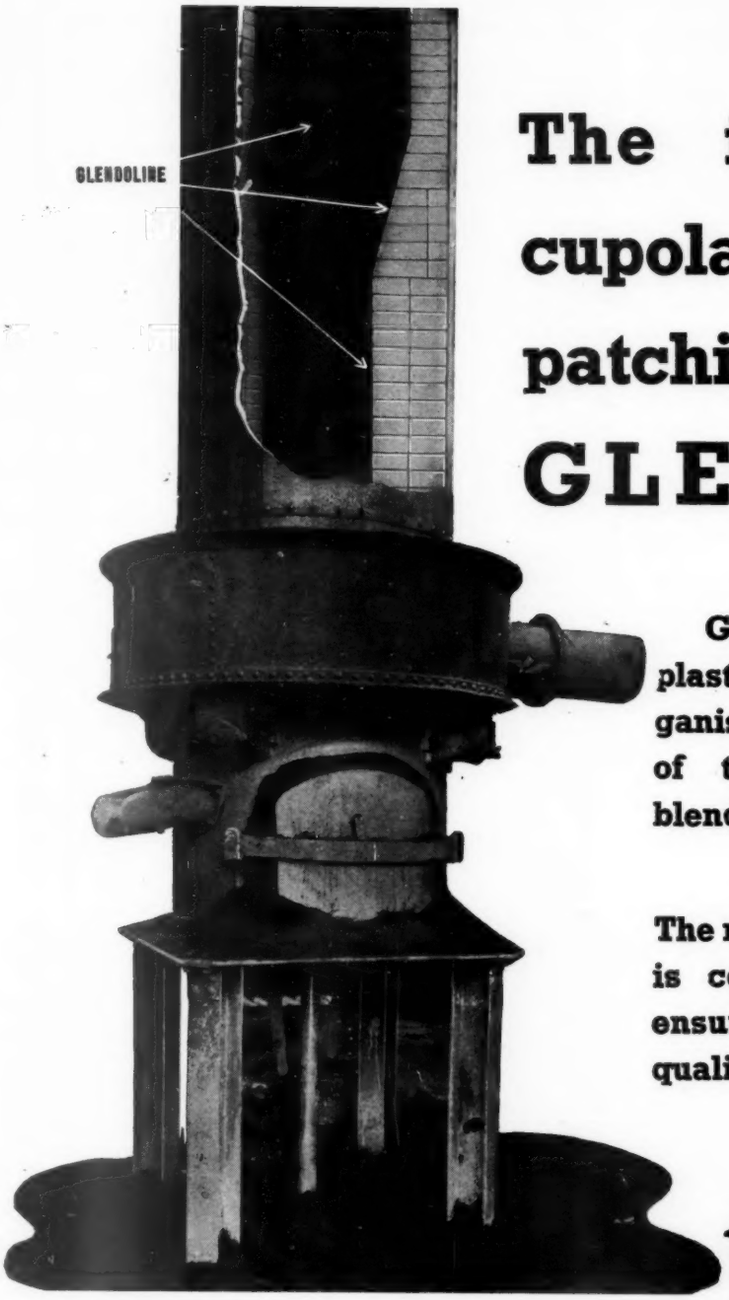
higher than for the longitudinal. No effect of grain can be observed on ultimate strength, but some evidence is given that transverse grain gives proportionately lower percentage elongation in heavier stock. This ties in with higher yield points.

Examination of the data for the enamelled sections indicates that failure of the enamel on stock of 8, 10 and 12 gauge will not occur until the yield point of the metal is approximated. Enamelling 14-gauge stock so strengthened the metal that in some instances the enamel was not cracked, the bare metal in the grip ends yielding first. Averaging the results and converting to pounds per sq. in., disregarding enamel thickness, the following data have been computed.

Stock gauge.	Unenamelled. Average yield point. Lbs.	Unenamelled. Average yield point. Lbs. per sq. in.	Enamelled. Average failure. Lbs.	Enamelled. Average failure. Lbs. per sq. in.
14	1,800	32,970	2,380	43,600
12	2,360	32,895	2,315	32,500
10	4,345	30,605	4,147	29,100
8	7,380	45,270	6,550	40,500

It will be noted that the results on enamelled 12-gauge and 10-gauge stock are comparable to unenamelled stock. The presence of the enamel on the 14-gauge metal strengthened it as explained above.

The discrepancy between the two averages on 8-gauge stock may be due somewhat to the slight normalising effect of the enamel fire as well as the fact that both unenamelled test-pieces were of transverse grain and therefore higher.



The ideal cupola lining and patching material . . .

GLENDOLINE

Glendoline is a carefully prepared plastic refractory, comprising ganister stone from a selected bed of the famous Sheffield quality, blended with a special clay.

The mixing and grading of Glendoline is controlled to a definite formula, ensuring dependable and uniform quality.

★ EXTREMELY PLASTIC

★ HIGHLY REFRACTORY

★ GREAT MECHANICAL STRENGTH

★ This photograph of a cupola, shows a portion of the lining and the positions where Glendoline is recommended for lining and patching.

Please write for full information and descriptive leaflet to :—

GENERAL REFRACTORIES Ltd.

Telephone : *Sheffield* 31113 (6 *lines*). **GENEFAX HOUSE, SHEFFIELD** *Telegrams :* *"Genefax, Sheffield"*

Raw Material Markets

INCREASE OF 9s. IN FOUNDRY PIG-IRON PRICES

The Control of Iron and Steel (No. 10) Order, made by the Minister of Supply, which came into force on Monday, varies Order No. 8 by substituting a fresh schedule of maximum prices for iron and steel products. The new prices represent additions of from 3s. 6d. to 9s. a ton for pig-iron and 22s. 6d. to 27s. 6d. for billets, with corresponding adjustments for other products. These advances are in the main to meet, from a central fund, further abnormal costs of imported materials under present conditions. They also include some allowance for the rises which have taken place in manufacturing costs since the outbreak of war, including recent increases in scrap prices and railway rates. The increase in foundry pig-iron prices is 9s. Hematite has been raised by 3s. 6d. per ton. In the case of castings, for rainwater and soil goods, gutters and connections, the new rates are the prices set out in the related schedules, with the addition of 8 per cent. plus 20s. per ton or an equivalent percentage. Prices for steel castings are those set out in the related schedules with the addition of 9 per cent., plus 17s. 6d. per ton.

The new rates for finished iron and steel products are incorporated in the price-list on page 12.

Conditions in the iron industry change very little from week to week; heavy engineers, being engaged almost solely on Government work, are in the market for substantial tonnages and, consequently, the full outputs of low-phosphorus iron and hematite are taken up as available. The light-castings trade, the chief user of high-phosphorus iron, does not improve to any extent, but production has been at a comparatively low ebb for a considerable time past, and there is now little surplus. Steelworks continue to operate to capacity.

Pig-Iron

MIDDLESBROUGH—Foundry-iron makers in the Cleveland area are concentrating on expanding their outputs to meet a growing demand from practically all sources of consumption. Owing to the present strength of demands from works producing Government requirements, there is little iron to spare for other users. All fresh orders are subject to authorisation by the Control and the makers' sole duty now is to provide the iron, the Control authorities deciding the destination of deliveries. Sufficient iron is forthcoming to meet urgent needs, but the ordinary domestic user now finds it very difficult to obtain licences. Iron for the light-castings foundries is being received in this district from the Midlands, the production of Cleveland iron being still suspended. Hematite is in insistent demand and producers are having to concentrate their attention on the satisfaction of the needs of concerns carrying out Government departments' orders. Both ordinary qualities and the special grades are in heavy request, but the supply position is not unsatisfactory.

LANCASHIRE—Priority consumers of foundry iron cannot complain at the attention accorded them by ironmakers, but there is increasing pressure on the outputs of Midland producers, and users not on Government lists are finding it more and more difficult to obtain their full requirements. Speciality engineers continue to be occupied to the limits of their capacity on work of national importance, but only a small amount of official work has as yet been found for the light-castings makers, most of whom are still quietly employed, owing to the falling away of building specifications and export orders. Consumers of hematite in the Lancashire district obtain their needs from West Coast plants and quite good deliveries continue to be made.

MIDLANDS—Low-phosphorus iron and hematite are both in demand by heavy engineering works. The outlook for heavy engineers in the Midlands is particularly active and local works are expected to play a still greater part in the munitions programme. High-phosphorus iron, although in much lesser demand than other irons, is not available, generally speaking, except for work of national importance, as supplies are on the small side owing to the comparatively meagre production of the past few months. Many furnaces formerly producing this type of iron have been transferred to other descriptions, as demand from the light-castings foundries has been on the quiet side. Thus, stocks are low and the position now has to be watched more carefully than before. Certain light-castings works have now converted their plants to deal with products in demand for munitions purposes, but, as yet, most makers are badly placed for work.

SCOTLAND—Trade in Falkirk and other centres of the light-castings industry continues to be rather quiet, but has been improved to some extent by the acquisition of small Government orders which, it is anticipated, will be increased in the course of time. At present, however, short time is still unavoidable at a number of factories. During the last war hand grenades were produced at these works on a substantial scale. Heavy engineers are working to full capacity on the production of war material.

Coke

Activity in the foundry coke market is very much greater than is usual at this time of the year, owing to the commendable desire of many consumers to accumulate large reserve stocks. Consumption, also, of course, is larger than in former years, but the ovens are able to make satisfactory deliveries. Forward contracts are being entered into, but a firm price cannot be quoted, as the Control may revise the existing price at any time such a move is found necessary. For delivery to Birmingham and Black Country stations, the current price of Durham best foundry coke is 55s. 6d. per ton, minimum.

Steel

Large as the production of British steelworks undoubtedly is, it is still essential to supplement deliveries from home sources by imports from the United States, while ore and scrap, too, have to be obtained from the other side of the Atlantic. Earlier in the war, of course, Belgian steel was used extensively in the United Kingdom, but military events have caused this source to dry up. The Mediterranean situation is still somewhat uncertain, and precautions against a cessation of iron-ore deliveries from this new theatre of war are well in hand. Steelworks are able to maintain their operations at full capacity, and no other policy is foreshadowed at present, as ample supplies of steelmaking materials are coming to hand.

Scrap

It was announced recently that the Government was to utilise its powers to make compulsory the collection of scrap metals. This would seem to be a wise move, as, although voluntary methods have resulted in very heavy tonnages becoming available for steelmaking purposes, there is no doubt that a considerable quantity of old metal is lying idle which will never reach the furnaces unless the owners are forced to sell. The effect of the new Order cannot be ascertained for a time, of course, but hopes are held that the furnaces will benefit to a large extent. Meanwhile, scrap collections in all parts of the United Kingdom continue to provide steelmakers with valuable material.

The Minister of Supply has made the Control of Iron and Steel (No. 9) (Scrap) Order, 1940, which revokes all existing acquisition licences under the Control of Iron and Steel (No. 7) (Scrap) Order, 1940, in so far as they apply to scrap-iron ingot moulds and scrap-iron ingot-mould bottom plates. In addition, the Order provides that no person shall treat, use or consume scrap-iron ingot moulds and bottom plates unless licensed to do so or otherwise authorised by the Minister of Supply. Finally, the Order fixes new maximum prices for scrap hematite-iron ingot moulds and hematite bottom plates.

The main purpose of the new Order is to ensure the best possible use being made of scrap-iron ingot moulds and scrap-iron ingot-mould bottom plates. Accordingly, under Article 1 of the Order, it is provided that all existing acquisition licences shall cease to authorise the acquisition of scrap-iron ingot moulds and bottom plates. Under Article 2 of the Order, no person may treat, use or consume scrap-iron ingot moulds and bottom plates unless he holds a licence authorising him so to do or is authorised by a special or general direction issued by the Minister of Supply. In addition to consumers having to obtain licences to acquire and treat, use or consume scrap-iron ingot moulds and bottom plates, it is now necessary for merchants to obtain licences not only to acquire, but also to treat the material, including breaking or cutting up the moulds into furnace or cupola sizes. Under Article 3 of the order the existing maximum prices for hematite ingot mould scrap are cancelled and new maximum prices are fixed applicable in all districts. The three conditions contained in the preamble to the Second Schedule to the Control of Iron and Steel (No. 7) (Scrap) Order, 1940, apply to the new maximum prices, and accordingly such prices may be increased by 2½ per cent. in the case of sales by *bona-fide* scrap iron and steel merchants carrying on business as such on September 22, 1939.

The maximum prices per ton for scrap hematite-iron ingot moulds and scrap hematite-iron ingot-mould bottom plates under the Order are:—

(1) For the manufacture of steel ingots, in furnace sizes not exceeding 5 ft. by 2 ft. by 1 ft. 6 in., £5 12s. 6d.

(2) For the manufacture of steel ingots, in furnace sizes not exceeding 3 ft. 6 in. by 1 ft. 6 in. by 1 ft. 6 in., £5 15s.

(3) For all other purposes, in cupola sizes, in pieces not exceeding 1½ cwts. in weight, £6 2s. 6d.

Metals

Following the signing of a Bill by President Roosevelt authorising the Reconstruction Finance Corporation to finance the acquisition of materials and equipment for national defence, the Corporation is negotiating for the purchase of large stocks of tin for American defence stocks. It is dealing directly with representatives of the International Tin Committee. A later report from Washington states that the Metals Reserve Company, a corporation created by the Reconstruction Finance Corporation, has agreed with the I.T.C. to buy 75,000 tons of tin, which will be held as reserve stock. This tin reserve will be purchased at 50 cents per lb., c.i.f. United States ports. The above report was confirmed in a British Colonial Office announcement on Monday, which stated that as a result of negotiations between representatives of the United States Government and representatives appointed for the purpose by the International Tin Committee, agreement has been reached for the purchase by U.S. Government organisation through normal trade channels of reserve stocks of tin. A company formed for the purpose would purchase all tin available as rapidly as it was available for purchase at a price of 50 cents per lb., c.i.f. United States ports, including war risks, with usual differentials for quality, deliveries, etc.

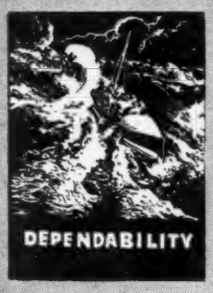
A meeting of the International Tin Committee will be held on July 8 to take any necessary measures in connection with this agreement. The way in which the I.T.C. will deal with the situation is a matter for conjecture; certain of the signatory countries are unable to fulfil their existing quotas, while in the past American consumers have shown a definite preference for Straits metal.

London Metal Exchange tin prices this week have been as follow:—

Cash—Thursday, £257 to £257 10s.; Friday, £257 to £257 5s.; Monday, £257 10s. to £258; Tuesday, £262 15s. to £263; Wednesday, £265 5s. to £265 10s.

Three Months—Thursday, £260 10s. to £260 15s.; Friday, £259 5s. to £259 10s.; Monday, £260 5s. to £260 10s.; Tuesday, £265 5s. to £265 10s.; Wednesday, £266 5s. to £266 10s.

The position of the American copper market remains unclarified following the developments arising out of the capitulation of France. Britain may take over a part of the French orders, but even this is uncertain, and nervousness is apparent in United States market circles. It is reported that efforts have been made to re-sell copper in bond at 10.75 cents per lb., f.a.s., but so far without success. The British Purchasing Commission has announced that on June 17 Great Britain took over all the French Government contracts for war supplies in the United States, but American copper market circles are not yet satisfied as to the future.



ALUMINIUM ALLOYS

YOUR BEST SOURCE of SUPPLY

Engineering and Industrial requirements dictate many variations in the specifications of Aluminium Alloys, that is why more and more foundrymen rely upon International Alloys Ltd., as their best source of supply. They know that with our wealth of experience and unrivalled production facilities we can be depended upon to produce Aluminium Alloys that consistently conform to the most exacting specification.

INTERNATIONAL ALLOYS LTD

SLOUGH · BUCKS

TELEGRAMS: INTALLOYD, SLOUGH ★ TELEPHONE: SLOUGH 23212

RAW MATERIALS—PRICE LIST

Wednesday, July 3, 1940

COPPER*

	£	s.	d.
Electrolytic	62	0	0
High-grade fire-refined	61	10	0
Fire-refined of not less than 99.7 per cent.	61	0	0
Do., do., 99.2 per cent.	60	10	0
Black hot-rolled wire rods	65	10	0

TIN

	£	s.	d.
Standard cash	265	5	0
Three months	266	5	0
Settlement	265	10	0
Official average Cash, June	273	12	10½
Do. Three Months, June	274	9	6
Do. Settlement, June	273	12	0

SPELTER*

	£	s.	d.
G.O.B. (foreign) (duty paid)	25	15	0
Do. (domestic)	26	10	0
"Prime Western"	26	10	0
Refined and electrolytic	27	5	0
Not less than 99.99 per cent.	28	15	0

LEAD*

	£	s.	d.
Good soft pig lead (foreign) (duty paid)	25	0	0
Do., do., (Empire and domestic)	25	0	0
English	26	10	0
Sheets, home	34	10	0
Do. export, f.o.b.	30	0	0
Pipes, home	34	0	0
Do. export, f.o.b.	30	10	0
Tea lead (nom.)		—	

ALUMINIUM

Ingots	£110
Wire, 10g.	£120
Sheets	1/2½ to 1/4½
Circles, 20/24g.	1/3 to 1/4

ZINC SHEETS, etc.

	£	s.	d.
Sheets, 10g. and thicker, ex works	39	2	6
Rolled zinc (boiler plates), ex works	37	2	6
Zinc oxide (Red Seal), d/d buyers' premises	28	7	6

ANTIMONY

	£	s.	d.
English	106	0	0
Foreign Regulus, duty paid	99	0	0
Chinese, prompt shipment, c.i.f.	81 0 0 to 85	0	0

QUICKSILVER

Quicksilver, ex-w'hse London 57 0 0 to 60 0 0

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	3s. 0d.
Finished bars, 18% tungsten	3s. 10d.
Finished bars, 22% tungsten	4s. 4d.

Per lb. d/d buyers' works.

NICKEL SILVER, etc.

	Per lb.
Ingots for raising	9d. to 1/3
Rolled—	
To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3½ to 1/9½
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/– to 1/8½
Wire round—	
to 10g.	1/6½ to 2/1½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/5½ upwards.

* Maximum prices per long ton delivered to buyers' premises.

FERRO-ALLOYS AND STEEL-MAKING METALS

(all prices nominal)

	£	s.	d.
Ferro-silicon—			
25%	18	10	0
40/50%	21	10	0
75%	31	0	0
Ferro-vanadium—			
35/50%	15/6 lb. Va.		
Ferro-molybdenum—			
70/75% carbon-free	6/– lb. Mo.		
Ferro-titanium—			
20/25% carbon-free	1/9 lb.		
Ferro-tungsten—			
80/85%	5/1 lb.		
Tungsten metal powder—			
98/99%	5/2½ lb.		
Ferro-chrome—			
2/4% car.	—		
4/6% car.	42	0	0
6/8% car.	42	0	0
8/10% car.	—		
Ferro-chrome—			
Max. 2% car.	1/0½ lb. Cr.		
Max. 1% car.	1/1½ lb. Cr.		
Max. 0.5% car.	1/1½ lb. Cr.		
70% carbon-free	1/3 lb. Cr.		
Nickel—99.5/100%	£190 to £195		
"F" nickel shot	175	0	0
Ferro-cobalt, 98/99%	8/9 lb.		
Metallic chromium—			
96/98%	3/9 lb.		
Ferro-manganese—			
76/80% loose	17	11	0
76/80% packed	19	1	0
Metallic manganese—			
94/96% carbon-free	1/9 lb.		

Per ton unless otherwise stated, basis 2-ton lots, d/d Sheffield works.

SCRAP*

	£	s.	d.	£	s.	d.
SOUTH WALES—						
Short heavy steel, not ex. 24-in. lengths	3	16	6	to 3	19	0
Heavy machinery cast iron			4	6	6	
Ordinary heavy cast iron			4	1	6	
Cast-iron railway chairs			4	6	6	
Medium cast iron			3	17	9	
Light cast iron			3	13	0	
MIDDLESBROUGH—						
Short heavy steel	3	14	3	to 3	16	9
Heavy machinery cast iron			4	11	3	
Ordinary heavy cast iron			4	8	9	
Cast-iron railway chairs			4	8	9	
Medium cast iron			3	19	0	
Light cast iron			3	14	0	
BIRMINGHAM DISTRICT—						
Short heavy steel	3	9	3	to 3	11	9
Hematite ingot mould			5	10	9	
Heavy machinery cast iron			4	11	9	
Ordinary heavy cast iron			4	7	0	
Cast-iron railway chairs			4	7	0	
Medium cast iron			3	19	9	
Light cast iron			3	14	9	
SCOTLAND—						
Short heavy steel	3	14	0	to 3	16	6
Heavy machinery cast iron			4	13	9	
Ordinary heavy cast iron			4	8	9	
Cast-iron railway chairs			4	13	9	
Medium cast iron			3	16	9	
Light cast iron			3	11	9	

* Delivered free to consumers' works in England and Wales. For deliveries of cast-iron scrap free to consumers' works in Scotland, the above prices less 3s. per ton, but plus actual cost of transport or 6s. per ton, whichever is the less. All prices: Plus 2½ per cent. dealers' remuneration: 50 tons and upwards over three months 2s. 6d. extra.

PIG-IRON*

	£	s.	d.
N.E. COAST (d/d Tees-side area)—			
Foundry No. 1	123/–		
„ No. 3	120/–		
„ No. 4	119/–		
Forge No. 4	119/–		
Hematite No. 1	131/–		
Hematite M/Nos.	130/6		
N.W. COAST—			
Hem. M/Nos. d/d Glas.	131/–		
„ d/d Birm.	142/6		
MIDLANDS (d/d Birmingham dist.)—			
Staffs No. 4 forge	121/–		
„ No. 3 fdry.	122/–		
Northants forge	118/6		
„ fdry. No. 3	119/6		
„ fdry. No. 1	122/6		
Derbyshire forge	121/–		
„ fdry. No. 3	122/–		
„ fdry. No. 1	125/–		
Phosphorus 0.5% to 0.75%	129/6		
Phosphorus 0.1% to 0.5%	132/6		
SCOTLAND—			
Foundry No. 1, Grangemouth	119/9		
„ No. 3, Grangemouth	117/3		
Cleveland No. 3, Glasgow	123/–		
„ „ Falkirk	120/–		
Scottish hem. M/Nos. d/d	131/–		
SHEFFIELD (d/d district)—			
Derby forge	118/6		
„ fdry. No. 3	119/6		
Lincs forge	118/6		
„ fdry. No. 3	119/6		
W.C. hematite	136/6		
LANCASHIRE (d/d eq. Man.)—			
Derby fdry. No. 3	125/–		
Staffs fdry. No. 3	125/–		
Northants fdry. No. 3	123/6		
Cleveland fdry. No. 3	125/–		
Cylinder and Refined Irons			
North Zone	168/–		
South Zone	170/6		
Refined Malleable			
Birmingham and S. Staffs	165/6		
Cold Blast			
South Staffs	217/–		

* Prices of hematite and basic pig-iron, and of foundry and forge iron with a phosphoric content of not less than 0.75 per cent., are subject to a rebate of 5s. per ton under certain conditions.

SEMI-FINISHED STEEL

Re-rolling Billets, Blooms and Slabs.

	£	s.	d.
BASIC:			
Soft, u.t., 100-ton lots	10	10	0
Tested, up to 0.25% C.	10	15	0
Tested, 0.25 to 0.33% C.	10	17	6
Tested, 0.33 to 0.41% C.	11	0	0
Hard (0.42 to 0.60% C.)	11	17	6
„ (0.61 to 0.85% C.)	12	7	6
„ (0.86 to 0.99% C.)	12	17	6
„ (1% C. and up)	13	7	6
Silico-manganese	14	5	0
Free-cutting	12	10	0
SIEMENS MARTIN ACID:			
Up to 0.25% C.	13	15	0
Case-hardening	14	12	6
Silico-manganese	14	10	0

Billets, Blooms and Slabs for Forging and Stamping.

Basic soft, up to 0.25% C.	12	2	6
Basic hard, 0.41 to 0.60% C.	12	10	0
Acid, up to 0.25% C.	14	5	0

Other Semi-products, etc.

Tin bars	10	7	6
Sheet bars	10	7	6
*Wire rods, soft basic	15	4	0
„ hard basic	18	12	6
„ free-cutting	17	12	6
„ acid	22	3	6

* Subject to rebate.

FINISHED STEEL

Usual district deliveries.

[A rebate of 15/- per ton for steel bars, sections, plates joists and hoops is obtainable in the home trade under certain conditions.]

	£	s.	d.
Plates, ship (N.E. Coast)	13	13	0
Boiler plts. (N.E. Coast)	15	0	6
Chequer plts. (N.E. Coast)	15	13	0
Angles, over 4 un. ins.	13	13	0
Tees, over 4 un. ins.	14	13	0
Joists, 3 in. × 3 in. and up	13	13	0
Rounds and squares, 3 in. to 5½ in.	14	13	0
Rounds under 3 in. to ⅜ in. (untested)	15	8	6
Flats—over 5 in. wide	13	18	0
„ 5 in. wide and under	15	8	6
Rails, heavy, f.o.t.	12	15	6
Hoops	16	3	6
Black sheets, 24 g. (4 t. lots)	19	7	6
Galv. cor. shts. („)	22	12	6
Galv. flat shts. („)	23	2	6
Galv. fencing wire, 8g. plain	24	7	6

FINISHED IRON

	£	s.	d.
CROWN IRON:			
England and Wales	15	2	6
Scotland	15	2	6
Ireland, f.o.q.	15	15	0
No. 3 BARS:			
England and Wales	12	5	0
Scotland	13	7	6
Ireland, f.o.q.	12	17	6
No. 4 BARS:			
England and Wales	12	15	0
Scotland	13	12	6
Ireland, f.o.q.	13	7	6
STRIP:			
England and Wales	—		
STAFFS MARKED BARS, f.o.t.	—		

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated, June 6, 1940.

	Dols.
No. 2 foundry, Phila.	24.84
No. 2 foundry, Valley	23.00
No. 2 foundry, Birm.	19.38
Basic, Valley	22.50
Malleable, Valley	23.00
Grey forge, Valley	22.50
Ferro-mang., seaboard	100.00
O.-h. rails, h'y, at mill	40.00
Billets	34.00
Sheet bars	34.00
Wire rods	2.00
	Cents.
Iron bars, Chicago	2.25
Steel bars	2.15
Tank, plates	2.10
Beams, etc.	2.10
Skelp, grooved steel	1.90
Steel strip	2.10
Steel sheets	2.10
Sheets, galv., No. 24	3.50
Wire nails	2.55
Plain wire	2.60
Tinplates, 100-lb. box	$5.00

COKE (at ovens)

Welsh foundry	42/6 to 44/–
„ furnace	31/6 to 33/–
Durham foundry	39/6
„ furnace	31/8
Scottish foundry	42/6 to 47/6
„ furnace	31/6

TINPLATES

f.o.b. Bristol Channel ports

I.C. cokes	20 × 14 per box		30/– to 31/–
„	28 × 20	„	60/– to 62/–
„	20 × 10	„	43/6 to 45/–
„	18¾ × 14	„	30/– to 31/–
C.W.	20 × 14	„	30/–
„	28 × 20	„	60/–
„	20 × 10	„	43/6
„	18¾ × 14	„	30/–

NON-FERROUS SCRAP

(Official Maximum Prices, per ton ex Works.)

	£	s.	d.
Bright untinned copper wire, in crucible form or in hanks	57	10	0
No. 1 copper wire	57	0	0
No. 2 copper wire	55	10	0
Copper firebox plates, cut up	57	10	0
Clear untinned copper, cut up	56	10	0
Braziery copper	53	10	0
Q.F. process and shell-case brass, 70/30 quality, free from primers	49	0	0
Clean fired 303 S.A. cartridge cases	47	0	0
70/30 turnings, clean and baled	43	0	0
Brass swarf, clean, free from iron and commercially dry	34	10	0
New brass rod ends, 60/40 quality	38	10	0
Hot stampings and fuse metal, 60/40 quality	38	10	0
Admiralty gunmetal, 88-10-2, containing not more than ½ per cent. lead or 3 per cent. zinc, or less than 9½ per cent. tin	72	0	0

NEW BRASS TUBES, etc.

	Per lb.
Solid drawn tubes	13½d.
Brazed tubes	15½d.
Rods, drawn	11½d.
Rods, extd. or rlld.	8½d.
Sheets to 10 w.g.	10½d.
Wire	10½d.
Rolled metal	9½d.
Yellow metal rods	8½d.

COPPER TUBES, etc.

Solid drawn tubes	14½d.
Brazed tubes	14½d.
Wire	9½d.

PHOSPHOR BRONZE

	Per lb. basis
Strip	13½d.
Sheet to 10 w.g.	13½d.
Wire	15½d.
Rods	15½d.
Tubes	20½d.
Castings	17d.

Delivery 3 cwt. free.
10% phos. cop. £35 above B.S.
15% phos. cop. £40 above B.S.
Phosphor tin (5%) £40 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

AVERAGE MONTHLY PRICES OF DERBYSHIRE NO. 3 FOUNDRY AT MANCHESTER.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
1904	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6	2 17 6
1905	2 13 0	2 13 0	2 11 6	2 12 6	2 12 0	2 12 0	2 12 3	2 12 3	2 14 0	2 16 6	3 0 0	3 0 6	2 14 1
1906	3 2 0	3 5 0	3 3 0	3 0 6	2 17 0	2 18 6	2 18 0	2 16 6	2 19 0	3 0 6	3 1 6	3 7 0	3 0 8½
1907	3 7 0	3 7 0	3 5 0	3 2 0	3 4 0	3 8 0	3 6 0	3 5 0	3 4 0	3 2 6	3 1 0	2 18 6	3 4 2½
1908	2 15 0	2 14 6	2 14 6	2 15 6	2 14 0	2 13 0	2 13 0	2 11 6	2 12 6	2 13 0	2 12	2 12 6	2 13 5½
1909	2 13 0	2 12 6	2 11 6	2 12 0	2 12 6	2 12 6	2 12 0	2 12 6	2 14 6	2 15 0	2 14 6	2 14 0	2 13 0½
1910	2 13 9	2 14 0	2 14 0	2 14 4	2 15 0	2 15 0	2 14 9	2 15 0	2 15 0	2 15 0	2 15 0	2 15 0	2 14 7½
1911	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 16 0	2 14 6	2 15 0	2 15 0	2 16 8
1912	2 17 4½	2 17 6	2 17 6	3 1 1½	3 2 6	3 3 9	3 6 3	3 7 6	3 10 10½	3 12 6	3 13 3½	3 14 6	3 5 4
1913	3 15 7	3 15 0	3 11 10½	3 11 4½	3 10 2½	3 6 10½	3 4 2½	3 2 9	3 1 9	3 1 0	2 19 3	2 17 2½	3 6 5
1914	2 17 2½	2 18 0	2 18 0	2 17 0	2 17 0	2 16 7½	2 16 0	3 2 10	3 1 0	2 19 9½	2 16 11½	2 18 1½	2 18 2½
1915	3 1 2	3 3 11	3 5 9	3 18 8½	3 13 7	3 14 1	3 15 0	3 13 3	3 12 0½	3 11 1	3 14 0	4 3 3	3 12 2½
1916	4 4 6½	4 11 6	4 11 6½	4 7 6	4 7 6	4 7 6	4 10 0	4 12 10	4 12 6	4 12 6	4 12 6	4 12 6	4 8 6
1917	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6
1918	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6	4 12 6
1919	4 12 6	4 12 6	4 12 6	4 12 6	7 5 0	8 8 5	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	9 0 0	7 3 10½
1920	9 13 9	10 0 0	10 5 3	10 15 3	11 10 0	12 2 6	12 5 0	13 1 3	14 7 6	14 5 0	14 5 0	14 5 0	12 12 1
1921	12 11 8	10 8 9	9 2 6	8 2 0	8 0 0	8 0 0	8 0 0	8 1 8	7 4 0	6 7 6	5 7 6	4 1' 10	8 0 2½
1922	5 5 0	4 17 6	4 15 0	4 15 0	4 12 6	4 12 6	4 12 6	4 12 6	4 11 3	4 10 0	4 10 0	4 10 0	4 13 7½
1923	4 12 8½	5 0 2	6 2 6	6 8 7½	6 2 5	5 11 9	5 9 1½	5 4 0	5 0 0	5 0 9	5 0 7	5 2 9	5 7 11½
1924	5 3 0	5 3 0	5 3 0	5 3 0	5 2 10	5 1 3	4 17 11	4 15 6	4 13 6	4 10 1½	4 10 0	4 10 3	4 17 9
1925	4 10 0	4 9 0	4 6 9	4 5 2½	4 3 0	4 0 1½	4 17 1½	3 15 7½	3 14 3½	3 13 4½	3 13 4½	3 13 2½	4 1 9
1926	3 14 9	3 15 3	3 15 6	3 15 3½	3 17 6	4 5 9	4 16 9	*	*	*	*	4 12 6	4 0 1½
1927	4 13 9½	4 13 3	4 11 1½	4 9 4½	4 6 1½	3 19 1½	3 16 1½	3 15 6	3 13 4½	3 13 4½	3 14 0	3 13 8½	4 1 6½
1928	3 13 2½	3 12 3½	3 12 3	3 12 3	3 11 6	3 10 0	3 8 3	3 7 8½	3 7 6	3 7 9½	3 8 3	3 7 6	3 9 10½
1929	3 8 3½	3 10 4½	3 10 10½	3 11 0	3 11 2½	3 12 0	3 12 4½	3 14 6	3 15 1½	3 17 0	3 17 0	3 17 0	3 13 1½
1930	3 17 0	3 17 0	3 17 0	3 17 0	3 17 0	3 17 0	3 15 0	3 12 0	3 12 0	3 12 0	3 10 1½	3 9 6	3 14 4½
1931	3 9 6	3 9 6	3 9 6	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 10
1932	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0
1933	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0	3 7 0
1934	3 7 0	3 9 6	3 13 2½	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 12 11½
1935	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 14 0	3 18 0	3 14 8	
1936	3 18 0	3 18 0	3 18 0	3 18 0	3 18 0	3 18 0	4 3 0	4 3 0	4 3 0	4 3 0	4 3 0	4 1 0	
1937	4 9 0	4 9 0	4 9 0	4 9 0	4 9 0	4 9 0	5 9 0	5 9 0	5 9 0	5 9 0	5 14 0	4 19 10	
1938	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	5 14 0	
1939	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 4 0	5 13 0	5 5 0	
1940	5 13 0	5 16 0	5 16 0	5 16 0	5 16 0	5 16 0	—	—	—	—	—	—	—

NOTE: Prices have been subject to a rebate of 5/- per ton since November 1, 1937. * No prices available during strike period.

WILLIAM JACKS & COMPANY
LIMITED
WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

CLARENCE CHAMBERS, 39, CORPORATION STREET, BIRMINGHAM.
13, RUMFORD STREET, LIVERPOOL.

PIG IRON

All grades FOUNDRY, HEMATITE, BASIC, SPECIALS, &c.

NON-FERROUS METALS
COPPER, TIN, LEAD, SPELTER, ANTIMONY, CHROME ORE.

WILLIAM JACKS & COMPANY
LIMITED
CENTRAL CHAMBERS, 93, HOPE ST., GLASGOW, C.2
ZETLAND ROAD, MIDDLESBROUGH.

Notice

Small Advertisements in this section of the Journal are accepted at the pre-paid rate of 6d. per line, first line in capitals counting two, average 6 words per line. Minimum charge for one insertion 3/-
(A remittance should accompany instructions.)

SITUATIONS VACANT AND WANTED

JUNIOR Assistant Metallurgical Chemist required for Marine Engineering Works in Belfast. Must have experience in iron and non-ferrous foundry materials. State age, experience and salary required.—Box 362, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

IRON FOUNDRY FOREMAN (40) requires position. Practical experience of light, medium and heavy work, green or dry sand. High class or repetition; also American experience of mass production methods. Willing to teach unskilled labour if required.—Box 364, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

EMPLOYMENT REGISTER.

Correspondence should be addressed to the General Secretary, Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester, from whom full particulars can be obtained of this service.

FOUNDRY FOREMAN or Assistant requires position. Accustomed to locomotive, colliery and general engineering castings of high grade character, jobbing and repetition. City and Guilds Certificate. (381)

POSITION required by advertiser in Grey Iron Foundry, whose experience embraces executive and administrative posts. Thorough knowledge of costing, production, commercial and sales departments. Extensive connections. (382)

EXPERIENCED FOUNDRY MANAGER requires re-engagement. Had full charge iron, brass foundries, pattern shop, well-known firms. High-grade general engineering castings including repetition and mechanised foundry experience. (383)

MACHINERY

CUPOLAS

6 ft. dia., 10 tons per hr.
3 ft. 6 in. dia., 3 tons per hr.
3 ft. dia., 2 tons per hr.
2 ft. 6 in. dia., 15-cwt. per hr. Cupolette.

PNEUMATIC MOULDING MACHINES

Macdonald Jolter, table 72 in. by 54 in.
Tabor 16-in. Shockless, table 72 in. by 48 in.
Tabor Portable Shockless Rollover, table 40 in. by 30 in.
Tabor ditto, table 27 in. by 20 in.
Tabor 14 in. by 16 in. and 21 in. by 16 in. squeeze.
Zimmerman Type R.P.W. 2 Jolt Squeeze turnover, table 36 in. by 20 in.
Mumford Type (Jackman) Swing Headpress, 13 in. by 15 in. and 14 in. by 16 in.
Mumford Pneumatic Core Jolters having 15-in. by 20-in. and 12-in. by 12-in. tables.
Rotoil Oil Sand Mixer.
50 Air Compressors; 500 Electric Motors, Dynamos, etc.

S. C. BILSBY, A.M.I.C.E., A.M.I.E.E.
CROSSWELLS ROAD, LANGLEY,
Nr. Birmingham.
'Phone: Broadwell 1359.

MACHINERY—*Continued*

THOS. W. WARD, LTD.

NINE first-class Wet-Back "Blake" Vertical Multitubular Boilers, 17 ft. 6 in. by 7 ft., re-insurable w.p. 160 lbs. per sq. in.

CROSS TUBE BOILER, oil-fired, 8 ft. 2 in. by 3 ft. 9 in., w.p. 80 lbs.

CROSS TUBE BOILER, 4 ft. by 2 ft. 3 in., w.p. 60 lbs.

Stocks good CAST IRON FLOORPLATES lying at Sheffield and elsewhere. Details upon application.

Write for "Albion" Catalogue
ALBION WORKS, SHEFFIELD
'Grams: "Forward." 'Phone: 23001 (15 lines).

WANTED a number of power jolt ram moulding machines with effective pattern draw of 6 in.; adaptable to boxes 16 in. by 14 in. by 24 in. by 18 in., 80 lbs. air pressure. Apply:—THE DAVIS GAS STOVE COMPANY, LIMITED, Diamond Foundry, Luton.

FOR SALE.—"Denbigh" No. 3. Hand Jolt, Turnover Moulding Machine. Table 22 in. by 22 in. in excellent condition.—Box 366, Offices of THE FOUNDRY TRADE JOURNAL, 3, Amersham Road, High Wycombe.

SAND MIXERS AND AERATORS.—The "Breakir" Centrifugal Machine is *THE* machine. Outputs 10 cwts. to 8 tons per hr.—W. BREALEY & CO. LTD., Station Works, Ecclesfield, Sheffield.

MISCELLANEOUS

"A STUDY IN ECONOMY"
ACTUAL MANUFACTURES
BY USING OUR

Foundry Blackings, Facings, Parting Powder, Core Gum, Terra Flake, Talc Coal Dusts, Ganister, Ceylon Plumbago (Imports direct) We definitely help to produce perfect Castings. Only the best minerals used in the making. A trial order will convince users of their economic value.

JOHN & C. DURRANS,
PENNINE WORKS, HAZLEHEAD,
NEAR SHEFFIELD.
Telephone: 128 Penistone. Telegrams: Facings, Penistone

'Phone: 22977 SLOUGH

Four "ADAPTABLE" HAND MOULDING MACHINES, rebuilt. £20 each.
JOLT SQUEEZE "JACKMAN" MOULDING MACHINES, 14" x 16", as new. £90 each.
Morgan 250 lb. Tilting Furnace.
Monometer ½-ton Semi-rotary.
NEW PIT FURNACES 150 lbs. capacity, oil or coke fired. £35 each.
NEW SHOTBLAST CABINET PLANTS with motor driven Exhaust Fans, complete, all sizes. Prompt delivery.
Several good "TABOR" Split Pattern Squeezer type Moulding Machines.
PLAIN JOLT RAM, with table 54 ins. square, cyl. 12 ins. dia. £90.

ALEX. HAMMOND, *Foundry Machinery Merchants.*
14, AUSTRALIA ROAD, SLOUGH
BUY FROM ME AND SAVE MONEY.

R. J. RICHARDSON & SONS, LTD.
COMMERCIAL STREET, BIRMINGHAM, 1
Airless and Pressure Blast Cleaning Plants
AIR COMPRESSORS
DUST ARRESTERS
CHILLED IRON SHOT—BLASTYTE
FOUNDRY EQUIPMENT
WE SHOT OR SAND-BLAST FOR ALL TRADES
Telephone: MIDLAND 2281 & 2282.

Ryland's Directory
(2,500 pages 8½" × 5½")
The standard work of reference covering the Coal, Iron, Steel, Tinplate, Metal, Engineering, Hardware and Allied Trades
1940 EDITION
Price 42/- cloth bound, 52/- leather
INDUSTRIAL NEWSPAPERS Ltd.
3, Amersham Road, High Wycombe
Telephone: High Wycombe 1752

PETER—WITH ONE EXCEPTION

With one exception Peter is an ordinary little fellow. Chubby, likeable, just five-and-a-half, full of life and fun and on occasions—be it admitted—of naughtiness.

Just now Peter's rather important, for this is his first term at school, and he's grappling with the intricacies of "A B C" and "Twice-Two": difficult subjects to all men of five-and-a-half, but even more difficult in Peter's case because—bad luck—he's totally blind. That's his One Exception.

Peter learns reading, writing, and 'rithmetic through the medium of "Braille"—dull stuff compared with the coloured picture books of most five-and-a-halfs. However, he's a stout lad is Peter, and he's making great progress.

Would you like to know more about him? How, in spite of his "One Exception," he is being educated and, when older, technically trained and usefully employed.

There is a long waiting list of "Peters" throughout the British Isles, for whom training and accommodation must be provided in the immediate future.

Will you help with a donation or annual subscription? Any sum, large or small, will be gratefully received.

Here's a suggestion. Your eyesight is worth 3d a year to you. Send Peter and his handicapped pals 3d for every year you've had it. Now, please, in case it slips your memory. Good idea?

The Chairman,
SCHOOL FOR THE BLIND
(Founded 1838)
SWISS COTTAGE, LONDON, N.W.3